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User's Guide for NASCRIN - A Vectorized Code for Calculating Two-Dimensional Supersonic Internal Flow Fields

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SUMMARY

A computer code has been developed for analyzing two-dimensional flow fields in supersonic combustion ramjet (scramjet) inlets. The code is written in the CYBER 200 FORTRAN language for the CDC® CYBER 203 vector-processing computer system. It solves the two-dimensional Euler or Navier-Stokes equations in conservation form by an unsplit, explicit, two-step finite-difference method. A more recent explicit-implicit, two-step scheme has also been incorporated in the code for the viscous flow analysis. An algebraic, two-layer eddy-viscosity model is used for the turbulent flow calculations. The code can analyze both inviscid and viscous flows with no strut, one strut, or multiple struts embedded in the flow field. Although the code is primarily written for supersonic internal flow, it can be used for a variety of other flow problems provided that suitable modifications are made to the boundary conditions. This report contains a listing of the program, descriptions of the input and output parameters, and a sample flow-field solution.

INTRODUCTION

A two-dimensional computer code NASCRIN (Numerical Analysis of SCRamjet INlet) has been developed to analyze scramjet-inlet flow fields. The code is based on the analysis developed in references 1 and 2. The analysis as such uses the two-dimensional Euler or Navier-Stokes equations in conservation form to describe the inlet flow. A two-layer eddy-viscosity model due to Baldwin and Lomax (ref. 3) is used for the turbulent flow calculation. In order to facilitate the use of a general inlet geometry with embedded bodies, an algebraic coordinate transformation is used which generates a set of boundary-fitted curvilinear coordinates (ref. 4). It transforms the physical domain into a rectangular domain with uniform mesh spacing, and embedded bodies in the flow field are transformed into slits (fig. 1). The transformation also allows for concentrating mesh lines in regions of high gradients. The transformed governing equations are solved by an unsplit, explicit, two-step finite-difference method due to MacCormack (ref. 5). This method is highly efficient on vector-processing computers, as it allows a high degree of vectorization. A more recent explicit-implicit scheme (refs. 6 and 7) has also been incorporated in the code for the viscous flow analysis and can be used upon the option of the user. As discussed in references 1 and 2, the code can also be used in a quasi-three-dimensional sense for a class of scramjet inlets under certain simplifying assumptions.

The code is written in the CYBER 200 FORTRAN language for the CDC® CYBER 203 vector-processing computer system at the Langley Research Center. In its present form, it can analyze two-dimensional inviscid and viscous (laminar and turbulent) flows with no strut, one strut, or multiple struts in the flow field. Although the code is primarily written for supersonic internal flow, it can be used for a variety of other flow problems, including subsonic inflow with supersonic outflow, supersonic inflow with subsonic outflow, or fully subsonic flow, by suitably modifying the boundary condition subroutines.

This report contains a brief description of the code structure, various input parameters, and output flow quantities. A listing of the program can be found in appendix A. A sample case is also presented to illustrate the use of the code.

CODE DESCRIPTION

The code listing given in appendix A is primarily set up for supersonic flow, although by making suitable changes in the boundary condition subroutines, it can be used for supersonic-subsonic or fully subsonic flow. For the supersonic flow case, the conditions at the inflow boundary are held fixed at some known values, and extrapolation is used at the outflow boundary. The code assumes a solid top boundary from the second grid point to the last grid point in the axial direction. In the case of a symmetric problem, the code solves the upper half of the flow field. (See examples in appendix B.)

The code consists of a main program, NASCRIN, and 20 subroutines. It has been structured in such a way that the user has to make changes only in the first few subroutines for a particular problem. A brief description of program NASCRIN and the various subroutines is given here in the order they appear in the code.

Program NASCRIN

Most input for parameters such as type of geometry, flow, and grid is done in NASCRIN. Each of these input parameters is discussed below. SI units are used throughout the code.

Line no.	Parameter	Description
NASCRIN 52	N1	Number of grid points in x-coordinate direction. It is also the second dimension in various arrays.
NASCRIN 53	M1	Number of grid points in y-coordinate direction. It is also the first dimension in various arrays.
NASCRIN 57	SWEEP	Sidewall sweep angle, Λ (fig. 1). If the code is to be used in a quasi-three-dimensional sense, define SWEEP in degrees; otherwise, set it to be zero.
NASCRIN 59	NSTRUT	NSTRUT = 0 for no strut embedded in the flow field; NSTRUT = 1 for a strut embedded in the flow field.
NASCRIN 62 NASCRIN 63 NASCRIN 64	NS1 NS2 MS	If NSTRUT = 0, NS1, NS2, and MS are not required. For NSTRUT = 1, NS1 and NS2 are grid points in the x-direction between which the strut lies. MS is the grid point in the y-direction through which an axial mesh line passes that is coincident with the top surface of the strut. (See examples in appendix B.)
NASCRIN 69	LSYM	A parameter for specifying the type of lower boundary. If the flow is symmetric about the lower boundary and only the upper half of the flow is being calculated, set LSYM = 1; otherwise, LSYM = 0.
NASCRIN 73	NCWL	If the lower boundary is fully or partially solid, set NCWL = 1. If it is a free boundary, set NCWL = 0.

Line no.	Parameter	Description
NASCRIN 74 NASCRIN 75	NCWL1 NCWL2	If NCWL = 0, NCWL1 and NCWL2 are not required. If NCWL = 1, NCWL1 and NCWL2 are the grid points in the x-direction between which there is a solid lower boundary (cowl, strut).
NASCRIN 117	NFLOW	NFLOW = 0 for inviscid flow; NFLOW = 1 for laminar flow; and NFLOW = 2 for turbulent flow. If NFLOW = 2, it is necessary to modify calls to the subroutine EDDY, which calculates eddy viscosity. These calls are made in subroutine TURB.
NASCRIN 123	LFI	LFI is the unit number from which the solution is read to restart the program. It is used only for ILT = 2, and its name must be defined on the program card.
NASCRIN 124	LFO	LFO is the unit number on which the output of the current run is saved. It also must be defined on the program card.
NASCRIN 127	ILT	ILT = 1 for the first run of the computer program; ILT = 2 for second and subsequent restarts.
NASCRIN 132	LMAX	LMAX is the maximum number of time-steps the current program will run. The program will stop after LMAX time-steps, print the complete solution, and save it on LFO. The following message is printed at the end of the solution: "PROGRAM TERMINATED ON LMAX."
NASCRIN 133	LW	LW is the number of time-steps after which an intermediate solution is printed. LMAX should be equal to or an integer multiple of LW.
NASCRIN 136	LEXIT	A parameter used to apply boundary conditions at the outflow boundary. LEXIT = 0 for zeroth-order extrapolation; LEXIT = 1 for first-order extrapolation.
NASCRIN 139	CRIT	Local convergence criterion. Convergence is defined as $\mathrm{ERROR} = \frac{\text{New density - old density}}{\text{Old density}} \frac{1}{\mathrm{FDT}} \frac{1}{\mathrm{LSTEP}}$ where LSTEP = Number of time-steps after which the convergence is checked. In the present code, LSTEP = 2. That is, after every two time-steps, quantity ERROR is calculated at each grid point, and if it is less than CRIT at all the grid points, the solution is assumed converged based on the local convergence criterion. The program then stops, prints the complete solution, and saves it on LFO. The following message is printed at the end of the solution: "PROGRAM TERMINATED ON LOCAL ERROR CRITERION." FDT is defined on line NASCRIN 219.

Line no.	Parameter	Description
NASCRIN 140	CRITAVG	Average or global convergence criterion. Average convergence is defined as $$\text{ERRORAVG} = \frac{\Sigma(\text{ERROR}^2)}{\text{Number of grid points}}$$ If ERRORAVG becomes less than CRITAVG, the program again stops based on the average error criterion. It prints the solution and saves it on LFO. The following message is printed at the end of the solution: "PROGRAM TERMINATED ON MEAN SORT ERROR CRITERION." CRITAVG should be one or two orders of magnitude smaller than CRIT.
NASCRIN 144 NASCRIN 145 NASCRIN 146	FM PF TF	These are the Mach number, pressure, and temperature, respectively, at the inflow boundary. SI units are used.
NASCRIN 170	IMET	IMET = 1 if transformation metric coefficients are to be printed at each grid point; otherwise, IMET = 0.
NASCRIN 171	BETA	BETA controls grid clustering near upper and lower boundaries. The program uses a stretching function that clusters the mesh lines equally near the boundaries. The stretching function can be changed by making changes in subroutine XY. BETA should be greater than 1. The closer it gets to 1, the higher the stretching (i.e., more points are clustered near the boundaries).
NASCRIN 217	CCIMPY	This parameter controls the artificial damping in the implicit stage of the explicit-implicit method (refs. 6 and 7). CCIMPY = 0 turns off the damping, and CCIMPY = 1 turns it on.
NASCRIN 218	FDTL	A parameter that allows the use of local time-step marching to speed up the convergence to steady state. If the local time-step is not used, set FDTL = 1. If the local time-step is to be used, set FDTL greater than 1. For example, if FDTL = 2, the time-step at a grid point cannot exceed twice the global minimum time-step. If at a grid point, the local time-step is less than two times the global minimum, the local time-step is used; otherwise, the time-step at the grid point is set equal to two times the global minimum.
NASCRIN 219	FDT	FDT is a constant multiplier used in the time-step calculations. In the present code, $$\text{Time-step} = \left(\text{FDT}\,\frac{\Delta y}{\lvert v\rvert + a}\right)_{\min}$$ over the entire grid. Here Δy is the grid spacing in the y-coordinate direction, v is the velocity in the y-direction, and a is the speed of sound at a grid point.

Line no.	Parameter	Description
NASCRIN 219 (cont.)	FDT	Set FDT < 1 for the fully explicit scheme. For the case of viscous flow calculations, if FDT > 1, the explicit-implicit scheme of MacCormack is turned on automatically.
NASCRIN 220 NASCRIN 223	CCP CCT	Coefficients in the artificial damping expression in the explicit stage. The damping expression has two parts, one of which depends on the pressure gradient and the other on the temperature gradient. CCP multiplies the first part, and CCT multiplies the second part. Typical values of CCP and CCT are in the neighborhood of 0.5 and should be kept as small as possible to keep the artificial damping contribution to a minimum.
NASCRIN 224	LKK	This parameter allows the user to try various values of FDT or CCP and CCT. For LKK = 2, only one set of values can be used. But, for LKK = 3, the user can specify two values of FDT or CCP and CCT. If the program detects a negative temperature in the flow field for the first value, it will restart the calculations with the second value. But, if the program proceeds normally with the first value, it will ignore the second value. (See appendix C for examples in using LKK.)
NASCRIN 237	TIMEL	TIMEL is the time required by the free stream to travel 3 times the length of the flow domain. For supersonic flows, it has been observed that the flow reaches steady state if the calculations have advanced in time to TIMEL. If the program does not stop because of local or average convergence criterion and LMAX is sufficiently large, then it will stop if the physical time TIME ⩾ TIMEL. Physical time TIME is obtained by summing up the global minimum time-step size from each time-step. The program again prints the solution and saves it also on LFO. The following message is printed at the end of the solution: "PROGRAM TERMINATED ON PHYSICAL TIME CONVERGENCE CRITERION."

Subroutine START

The x,y coordinates of the upper and lower boundaries are prescribed in subroutine START between lines START 27 and START 78. For example, if the strut EFGH is removed from figure 1(c), define the x,y coordinates of lines APQRD and BC between the above-mentioned lines in START. However, if there is a strut in the flow field as shown in figure 1(c), define the x,y coordinates of lines APQRD and UEHGV between lines START 27 and START 61, and define the x,y coordinates of lines UEFGV and BC between lines START 64 and START 78. Grid points on lines UE and GV for lower and upper portions should have the same x,y coordinates. All the distances should be defined in meters.

For a quasi-three-dimensional application of the code in scramjet-inlet calculations, geometry should be prescribed in a plane normal to the sidewall sweep.

Subroutine TURB

Subroutine TURB is called in subroutine VISCOUS at line VISCOUS 222 for turbulent flow calculations (i.e., when NFLOW = 2). Subroutine TURB, in turn, calls subroutines VORT and EDDY to calculate eddy viscosity. It may be necessary to make several calls to subroutine EDDY in order to cover the entire flow field. (See examples in appendix B.)

There are six parameters in the call to subroutine EDDY. These parameters are described below:

NNX1,NNX2 NY1, NY2	Grid numbers in the x,y coordinate directions, respectively, for the flow domain being considered in a particular call to subroutine EDDY.
NWALL	NWALL = 1 when there is only one solid boundary (i.e., a wall) at NY2; NWALL = 2 when there are solid boundaries at both NY1 and NY2.
NSTR	NSTR = 1 for the region in which the lower strut surface forms the upper solid boundary of the flow domain. In this case, set NY2 = MS1; otherwise, NSTR = 0.

Subroutine XY

Subroutine XY performs the algebraic coordinate transformation and stretches the grid toward the upper and lower boundaries. Transformation metric coefficients are also calculated in this subroutine.

Subroutines VISCOUS and INVICID

Subroutine VISCOUS is called at line NASCRIN 241 for viscous (laminar and turbulent) flow calculations, and subroutine INVICID is called at line NASCRIN 240 for inviscid flow calculations. Both subroutines generate a starting solution for the first run of the program (ILT = 1) and read the solution from file LFI for second and subsequent runs (ILT = 2). Subroutines for flux vectors, damping, and boundary conditions are called in these subroutines, and the finite differencing for predictor and corrector steps is also done here. After the program is terminated either on a convergence criterion or on LMAX, subroutine PRINT is called to print the solution, and the solution is saved on file LFO.

In the case of subroutine VISCOUS, if FDT > 1, subroutines IMPY and VECIM2 are called to apply the implicit stage of the explicit-implicit method. This method is applied only in the y-coordinate direction because for a viscous flow calculation, the grid is highly compressed in the y-coordinate direction near the boundaries, which makes the minimum grid spacing in the y-direction much smaller than the minimum grid spacing in the x-direction. Because of this large difference in spacings, even if an implicit stage was incorporated in the x-direction, it would not be used.

Sometimes it is necessary to use a small value of FDT or a large value of damping coefficients CCP and CCT to keep the calculations stable in the initial stages, probably because the starting solution is a poor guess. But as the calculations progress, it is possible to gradually increase the time-step by increasing FDT or to decrease damping by decreasing CCP and CCT to a desired value over a number of time-steps. In the present program, these changes in FDT or CCP and CCT can be incorporated by inserting a few cards after line VISCOUS 51 and after line INVICID 60. Several examples of implementing these changes are given in appendix D.

Subroutines DVISCP and DVISCC

Subroutines DVISCP and DVISCC are called only for viscous flow calculations. Both subroutines calculate the viscous dissipation terms in the Navier-Stokes equations. Subroutine DVISCP uses backward differencing, and subroutine DIVSCC uses forward differencing in the calculation of these terms.

Subroutines VEC1 and IVEC1

Subroutines VEC1 and IVEC1 calculate the flux vectors for viscous and inviscid flow, respectively.

Subroutines DAMPP and DAMPC

Subroutines DAMPP and DAMPC are used to add artificial damping in the flux vectors. Subroutine DAMPP uses backward differencing, and subroutine DAMPC uses forward differencing in the calculation of damping terms.

Subroutine VEC2

Subroutine VEC2 is called after the predictor or corrector step. It calculates local flow quantities from the conserved variables.

Subroutine BOUND

Subroutine BOUND applies the boundary conditions for the viscous flow. The subroutine is set up for supersonic inflow and outflow boundaries. It applies a no-slip boundary condition on the upper boundary from the second grid point to the last grid point. The lower boundary can be either a solid wall, a free boundary, or a symmetry line. The conditions are held fixed at some prescribed values at the inflow boundary, and zeroth- or first-order extrapolation is used at the outflow boundary.

To use the program for supersonic inflow and subsonic outflow, the user needs to prescribe a back pressure at the outflow boundary. This can be done by changing line BOUND 76 for LEXIT = 1 or line BOUND 82 for LEXIT = 0 to the line P(1,N1;M1) = PB where PB is the back pressure in pascals.

It is also possible to modify the code for a subsonic inflow boundary. The user should insert the proper boundary conditions for subsonic inflow after line BOUND 33.

Subroutine IBOUND

Subroutine IBOUND applies the boundary conditions for the inviscid flow. This subroutine is also set up for supersonic inflow and outflow boundaries, although changes similar to those suggested in subroutine BOUND can be made to modify it to handle a subsonic inflow or subsonic outflow boundary.

Both subroutines BOUND and IBOUND check for negative temperature in the field during each predictor and corrector step. Anytime a negative temperature occurs in the field, the code prints the following message: "NEGATIVE TEMPERATURE IN THE FIELD." It then prints the number of time-steps at which the negative temperature occurred and the values of all the flow variables at each grid point. This allows the user to examine the flow variables in the region where the calculations became unstable. After this, the code returns to statement 1000 at line NASCRIN 221. It either restarts with a new value of time-step or damping parameters, or stops.

Subroutines VORT and EDDY

Subroutines VORT and EDDY calculate the eddy viscosity from the algebraic turbulence model of reference 3. Subroutine VORT calculates the vorticity at all the grid points. The vorticity is then used in subroutine EDDY to calculate the eddy viscosity. The parameters in subroutine EDDY were discussed earlier in subroutine TURB.

Subroutines IMPY and VECIM2

Subroutines IMPY and VECIM2 are used only for the viscous flow calculations to apply the implicit stage in the y-direction of the explicit-implicit method. Subroutine IMPY actually applies the implicit stage, and then subroutine VECIM2 calculates the flow variables at each grid point from the conserved variables, calls subroutine BOUND, and saves the flux quantities on the appropriate upper or lower boundary for the implicit stage of the next time-step. The implicit stage is used only when FDT > 1.

Subroutine SPILL

Subroutine SPILL is called after every LW time-steps at line VISCOUS 244 for the viscous flow and at line INVICID 172 for the inviscid flow. The purpose of this subroutine is to calculate the spillage in a quasi-three-dimensional application of the code. It takes the solution in the plane normal to the sidewall sweep and projects it back to the cowl plane. The constant tangential velocity component is then properly superimposed on the projected solution to provide the solution in the cowl plane. Knowing the component of velocity normal to the plane of the cowl and the density field, flow spillage (i.e., the amount of flow leaving the inlet ahead of the cowl) can be obtained. For viscous flow calculations, an arbitrary boundary-layer profile is prescribed on the constant tangential velocity component before superimposing it on the projected solution. In subroutine SPILL, it is assumed that the tangential velocity changes from zero to the constant inviscid value over 10 to 12 grid points from the solid boundary. For the case of zero sweep, obviously the spillage in the quasi-three-dimensional application of the code will be zero. For this case, the subroutine will skip the spillage calculations.

Subroutine SPILL also calculates and prints the nondimensional pressure on the upper and lower boundaries and on the upper and lower strut surfaces if there is a strut in the flow field. The pressure is nondimensionalized with respect to the pressure at the inflow boundary.

Subroutine PRINT

Subroutine PRINT is called after every LW time-steps and after the normal termination of the program. It prints the complete flow-field solution at all the grid points. It also prints certain input parameters and the mass flux across a given axial location.

SAMPLE PROBLEM AND OUTPUT QUANTITIES

To illustrate the use of the code, the listing given in appendix A is set up for a quasi-three-dimensional application of the code for the inlet geometry shown in figure 1. The geometry input in subroutine START is in a plane normal to the sweep line (fig. 1(c)). Only the upper half of the problem is solved. The problem is set up to calculate turbulent flow at Mach 5. The following values of input parameters have been used:

N1 = 55

M1 = 61

SWEEP = 30

NSTRUT = 1

NS1 = 16

NS2 = 46

MS = 29

LSYM = 1

NCWL = 1

NCWL1 = 24

NCWL2 = 44

NFLOW = 2

$\left.\begin{array}{l}\text{LFI = 9}\\ \text{LFO = 9}\end{array}\right\}$ (The program card equates UNIT9 to CASE20 at line NASCRIN 2. CASE20 is the name of the file on which the solution is saved.)

ILT = 1

LMAX = 25000

LW = LMAX

LEXIT = 1

CRIT = 0.0001

CRITAVG = 0.1 * CRIT

FM = 5. (FM is the Mach number at the face of the inlet in the plane normal to the sweep line.)

PF = 10000.

TF = 300.

IMET = 1

BETA = 1.005

FDTL = 1.

FDT = 1

CCP = 0.5

CCT = CCP

TIMEL = 3. * x(1,N1)/UF (UF is the velocity at the face of the inlet corresponding to Mach 5.)

To calculate eddy viscosity, five calls to subroutine EDDY are made in subroutine TURB as shown in the listing in appendix A. As mentioned earlier, for the quasi-three-dimensional application of the code, the flow is calculated in a plane normal to the sidewall sweep. The code prints the detailed solution in this plane. It then calculates the spillage from the inlet by projecting the solution to a plane parallel to the cowl plane and properly superimposing on it the component of velocity parallel to sweep line. The sample outputs are presented in appendix E, and a brief description of output quantities is given below.

Since parameter IMET is set equal to 1, the code prints the metric coefficients at all the grid points. In this portion of the output,

N grid number in x-direction

M grid number in y-direction

X distance in x-direction, m

Y distance in y-direction, m

XXI $= \frac{\partial x}{\partial \xi}$

YXI $= \frac{\partial y}{\partial \xi}$

XETA $= \dfrac{\partial x}{\partial \eta}$

YETA $= \dfrac{\partial y}{\partial \eta}$

AJ $= \dfrac{\partial x}{\partial \xi}\dfrac{\partial y}{\partial \eta} - \dfrac{\partial y}{\partial \xi}\dfrac{\partial x}{\partial \eta}$

where ξ, η are the coordinate directions in the transformed plane.

The code then prints the maximum error and mean square root error after every 50 time-steps till it stops either on LMAX or on one of the convergence criteria. It then prints the total number of time-steps (or iterations), the physical time advanced in seconds, and the time-limit in seconds. (Time-limit is set by the parameter TIMEL.) It also prints the values of CRIT (local error), CRITAVG (average error), and LEXIT (order of extrapolation at outflow). The complete solution is then printed at each body station in the x-direction. It includes

X,Y coordinates of the grid point, m

U,V axial and normal velocities, m/sec

P pressure, Pa

T temperature, K

RO density, kg/m^3

SH static enthalpy, m^2/sec^2

VIST turbulent viscosity, kg/m-sec

ERRO local error at a grid point

For NSTRUT = 1, flow variables at M = MS between N = NS1 to NS2 correspond to the top surface of the strut. Flow variables at the lower surface are printed separately. At the lower surface of the strut, the code prints total enthalpy HS and laminar viscosity VISS in place of VIST and ERRO.

With each call to subroutine PRINT, after printing the detailed solution, the code prints the mass flow rate at each axial station. This allows the user to check for mass conservation inside the inlet.

After the code stops on LMAX or any of the convergence criteria, it calls subroutine SPILL, which calculates flow spillage. If the sweep angle is zero, spillage calculations are not done. A sample output for spillage calculations is shown in appendix E. In this output, XP is the projected axial distance in the cowl place (i.e., $XP = X/\cos \Lambda$). Local mass spilled (in kilograms per meter-second) is the integrated value of the product of density and downward velocity component at a given XP location. Total mass spilled (in kilograms per second) is obtained by integrating the local values up to a given XP location. If, for example, the cowl closure starts at XP = 0.132791 m, corresponding to body station 40, the total mass spilled ahead of the cowl is equal to 0.01193 kg/sec. The user can then calculate the spillage in terms of the percentage of the incoming mass flow rate at the face of the three-dimensional inlet.

Subroutine SPILL also calculates and prints the surface pressure distribution on the top and bottom (or centerline in the case of a symmetric problem) boundaries and on the upper and lower strut surfaces for NSTRUT = 1. These pressures are nondimensionalized with respect to the pressure at the face of the inlet.

Finally, the code prints a message that tells on what basis the calculations were terminated.

From the solution of the sample problem presented here, pressure contours and the velocity vector field were plotted. These plots are shown in figures 2 and 3, respectively. Although only the upper half of the inlet was solved, the results were projected to the lower half of the inlet for plotting purposes.

COMPUTATIONAL RATE AND TIME REQUIREMENTS

The code is operational on the CDC CYBER 203 computer system and is highly vectorized to take full advantage of the vector-processing capability of the system. With the explicit method, it has a computational rate of 2×10^{-5} second per grid point per time-step for viscous flow and 1.3×10^{-5} second per grid point per time-step for inviscid flow when the 64-bit word arithmetic is used. The code can easily be modified to use the 32-bit word arithmetic, in which case, the computational rate is improved by a factor of about 2.5. For example, the code can perform approximately 50 time-steps per second for viscous flow and 75 time-steps per second for inviscid flow on a grid of 51×51 when the explicit method is used with the 32-bit word arithmetic. An inviscid problem using a 51×51 grid and requiring 1000 time-steps for convergence can be solved in about 15 seconds.

Finally, in the case of viscous flow calculations with very fine mesh spacing near the solid boundaries, a significant improvement in computational rate can be obtained by using the explicit-implicit method.

CONCLUDING REMARKS

A vectorized computer program NASCRIN has been developed that solves the two-dimensional Euler or Navier-Stokes equations in conservation form. It primarily uses MacCormack's explicit method, but for viscous flow calculations, MacCormack's explicit-implicit method can also be used at the user's discretion. An algebraic, two-layer eddy-viscosity model is used for the turbulent flow calculations. The code can analyze problems with or without embedded bodies in the flow field. It is highly user oriented and is structured in such a way that for most supersonic flow problems, the user has to make changes only in the main program and first two subroutines. Although the code is primarily written for supersonic internal flow, it can be used with some modifications for a variety of other flow problems.

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APPENDIX A

PROGRAM LISTING

```
      PROGRAM NASCRIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,            NASCRIN
     1UNIT9=CASE20)                                                     NASCRIN
C*********************************************************************NASCRIN
C NASCRIN STANDS FOR NUMERICAL ANALYSIS OF SUPERSONIC COMBUSTION       NASCRIN
C RAMJET INLETS.                                                       NASCRIN
C                                                                      NASCRIN
C THIS PROGRAM IS BASED ON AIAA PAPER NO. 81-185, NASA TP 1940,        NASCRIN
C AND NASA TP 1934, ALL BY AJAY KUMAR OF NASA LANGLEY RESEARCH CENTER. NASCRIN
C                                                                      NASCRIN
C THE PROGRAM SOLVES THE TWO-DIMENSIONAL NAVIER-STOKES EQUATIONS FOR   NASCRIN
C LAMINAR AND TURBULENT FLOW AND TWO-DIMENSIONAL EULER EQUATIONS FOR   NASCRIN
C INVISCID FLOW IN FULLY CONSERVATIVE FORM.                            NASCRIN
C                                                                      NASCRIN
C IT USES MACCORMACK'S UNSPLIT, EXPLICIT FINITE-DIFFERENCE METHOD.     NASCRIN
C                                                                      NASCRIN
C FOR VISCOUS FLOW, MACCORMACK'S EXPLICIT-IMPLICIT SCHEME CAN ALSO BE  NASCRIN
C USED AT USER'S OPTION.                                               NASCRIN
C                                                                      NASCRIN
C TURBULENCE IS MODELED BY BALDWIN-LOMAX MODEL.                        NASCRIN
C                                                                      NASCRIN
C AN ALGEBRAIC COORDINATE TRANSFORMATION IS USED TO GENERATE A SET OF  NASCRIN
C BOUNDARY FITTED CURVILINEAR COORDINATES.                             NASCRIN
C                                                                      NASCRIN
C OPERATIONAL ON CDC-CYBER-203 VECTOR PROCESSING COMPUTER.             NASCRIN
C                                                                      NASCRIN
C*********************************************************************NASCRIN
      BIT B1                                                           NASCRIN
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 NASCRIN
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                              NASCRIN
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3   NASCRIN
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                      NASCRIN
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),          NASCRIN
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                        NASCRIN
     2 PS(55),TS(55),SHS(55),HS(55)                                     NASCRIN
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)             NASCRIN
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),         NASCRIN
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)         NASCRIN
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)        NASCRIN
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)                NASCRIN
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),                NASCRIN
     1 XETA(61,55),YETA(61,55),AJ(61,55)                                NASCRIN
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),              NASCRIN
     1 YSETA(55),AJS(55)                                                NASCRIN
      COMMON/F9/INT(55),TE1(55),TE2(55),TE3(55),TE4(55)                 NASCRIN
      COMMON/F10/DT(61,55),DTM                                          NASCRIN
      COMMON/F11/ERRO(61,55),B1(61,55)                                  NASCRIN
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,    NASCRIN
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG                                  NASCRIN
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF        NASCRIN
      COMMON/F14/DAU(61,55,4),BDAU(55,4),BDAUS(55,4),TI(55,5),          NASCRIN
     1CCIMPY,GM1,GM2,GM3,GM4,GM5                                        NASCRIN
      N1=55                                                             NASCRIN
      M1=61                                                             NASCRIN
C     DEFINE SIDEWALL SWEEP.  IF THE FLOW IS BEING CALCULATED IN A PLANENASCRIN
C     NORMAL TO SIDEWALL SWEEP, DEFINE SIDEWALL SWEEP IN DEGREES.       NASCRIN
C     OTHERWISE EQUATE IT TO ZERO.                                      NASCRIN
      SWEEP=30.                                                         NASCRIN
C     NSTRUT=0 FOR NO STRUT CASE. NSTRUT=1 FOR A STRUT IN THE FLOW.     NASCRIN
      NSTRUT=1                                                          NASCRIN
C     STRUT IS LOCATED BETWEEN NS1 AND NS2 MESH POINTS IN XI DIRECTION  NASCRIN
C     AND IS COINCIDENT WITH MESH MS IN ETA DIRECTION.                  NASCRIN
      NS1=16                                                            NASCRIN
      NS2=46                                                            NASCRIN
      MS=29                                                             NASCRIN
C     LSYM IS A PARAMETER FOR THE LOWER BOUNDARY.                       NASCRIN
C     IF THE LOWER BOUNDARY IS A SYMMETRY LINE AND                      NASCRIN
C     WE ARE SOLVING ONLY UPPER HALF OF THE FLOW DOMAIN,  LSYM=1        NASCRIN
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C     IF THE LOWER BOUNDARY IS NOT A SYMMETRY LINE,  LSYM = 0             NASCRIN
      LSYM=1                                                              NASCRIN
C     NCWL1 AND NCWL2 ARE THE MESH POINTS BETWEEN WHICH COWL OR THE       NASCRIN
C     CENTER STRUT IS LOCATED.  IF THERE IS NO COWL OR STRUT ON THE       NASCRIN
C     CENTER LINE, SET NCWL = 0 OTHERWISE SET = 1 .                       NASCRIN
      NCWL=1                                                              NASCRIN
      NCWL1=24                                                            NASCRIN
      NCWL2=44                                                            NASCRIN
C                                                                         NASCRIN
      N11=N1-1                                                            NASCRIN
      N12=N1-2                                                            NASCRIN
      N13=N1-3                                                            NASCRIN
      M11=M1-1                                                            NASCRIN
      M12=M1-2                                                            NASCRIN
      M13=M1-3                                                            NASCRIN
      NXM=N1*M1                                                           NASCRIN
      NXM1=NXM-1                                                          NASCRIN
      NXM2=NXM-2                                                          NASCRIN
      NXM3=NXM-2*M1                                                       NASCRIN
      NXM4=NXM3-2                                                         NASCRIN
      NXM5=NXM-4*M1-2                                                     NASCRIN
      NXM6=NXM-2*M1-4                                                     NASCRIN
      NXM7=NXM-4*M1-4                                                     NASCRIN
      NS1M1=NS1-1                                                         NASCRIN
      NS1M2=NS1-2                                                         NASCRIN
      NS1P1=NS1+1                                                         NASCRIN
      NS2M1=NS2-1                                                         NASCRIN
      NS2P1=NS2+1                                                         NASCRIN
      NNS=N1-NS1M1                                                        NASCRIN
      NS=NS2-NS1+1                                                        NASCRIN
      NSM1=NS-1                                                           NASCRIN
      MS1=MS-1                                                            NASCRIN
      MS2=MS-2                                                            NASCRIN
      MS3=MS-3                                                            NASCRIN
      MS4=MS-4                                                            NASCRIN
      MSP1=MS+1                                                           NASCRIN
      MSP2=MS+2                                                           NASCRIN
      MSP3=MS+3                                                           NASCRIN
      NCWLM=NCWL1-1                                                       NASCRIN
      NCWLP=NCWL2+1                                                       NASCRIN
C     NFLOW IS A PARAMETER FOR THE TYPE OF FLOW. NFLOW= 0, 1 OR 2         NASCRIN
C     DEPLENDING ON WHETHER THE FLOW IS INVISCID, LAMINAR OR TURBULENT.   NASCRIN
C*****************************************************************        NASCRIN
C IF NFLOW=2, IT IS NECESSARY TO MODIFY THE CALLS TO SUBROUTINE EDDY      NASCRIN
C WHICH ARE FOUND IN SUBROUTINE TURB.                                     NASCRIN
C THE ENTIRE FLOW FIELD MAY HAVE TO BE DIVIDED INTO SEVERAL SUB-          NASCRIN
C DOMAINS AND MORE THAN ONE CALL TO SUBROUTINE EDDY MAY BE REQUIRED.      NASCRIN
C SEE EXAMPLES IN USER'S MANUAL FOR FURTHER CLARIFICATION.                NASCRIN
C***********************************************************************NASCRIN
      NFLOW=2                                                             NASCRIN
C     LFI IS THE PERMANENT FILE NUMBER FROM WHICH THE SOLUTION IS         NASCRIN
C     READ TO RESTART THE PROGRAM.  LFI IS REQUIRED ONLY WHEN ILT=2.      NASCRIN
C     LFO IS THE PERMANENT FILE NUMBER ON WHICH THE OUTPUT OF THE         NASCRIN
C     CURRENT COMPUTER RUN IS STORED.  BOTH LFI AND LFO SHOULD BE         NASCRIN
C     DEFINED ON THE PROGRAM CARD.                                        NASCRIN
      LFI=9                                                               NASCRIN
      LFO=9                                                               NASCRIN
C     SET ILT=1 FOR THE FIRST RUN OF THE COMPUTER PROGRAM.                NASCRIN
C     TO RESTART THE PROGRAM, SET ILT=2                                   NASCRIN
      ILT=1                                                               NASCRIN
C     LMAX IS THE MAXIMUM NUMBER OF TIME-STEPS.  THE PROGRAM WILL         NASCRIN
C     STOP AFTER LMAX TIME-STEPS AND WILL STORE THE SOLUTION ON LFO.      NASCRIN
C     AN INTERMEDIATE SOLUTION IS PRINTED AFTER EVERY LW TIME-STEPS.      NASCRIN
C     LMAX SHOULD BE EQUAL TO OR AN INTEGER MULTIPLE OF LW.               NASCRIN
      LMAX=25000                                                          NASCRIN
      LW=LMAX                                                             NASCRIN
C     LEXIT=0 FOR ZERO ORDER EXTRAPOLATION AND LEXIT=1 FOR FIRST ORDER    NASCRIN
C     EXTRAPOLATION AT THE OUTFLOW BOUNDARY.                              NASCRIN
      LEXIT=1                                                             NASCRIN
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C     ERROR CRITERION                                                NASCRIN
C     CRITAVG IS THE AVERAGE ERROR OVER THE ENTIRE FLOW FIELD        NASCRIN
      CRIT=.0001                                                     NASCRIN
      CRITAVG=0.1*CRIT                                               NASCRIN
C                                                                    NASCRIN
C     CONDITIONS AT THE FACE OF THE INLET.  USE SI UNITS.            NASCRIN
C     (P IN N/M2 AND T IN K)                                         NASCRIN
      FM=5.                                                          NASCRIN
      PF=10000.                                                      NASCRIN
      TF=300.                                                        NASCRIN
      GAMA=1.4                                                       NASCRIN
      RGAS=287.                                                      NASCRIN
      CP=GAMA*RGAS/(GAMA-1.)                                         NASCRIN
      GM1=GAMA-1.                                                    NASCRIN
      GM2=GM1/GAMA                                                   NASCRIN
      GM3=CP/GAMA                                                    NASCRIN
      PR=.72                                                         NASCRIN
      PRT=.9                                                         NASCRIN
      GM4=2.*GAMA/PR                                                 NASCRIN
      GM5=GAMA*RGAS                                                  NASCRIN
C     CVIS IS THE COEFFICIENT USED IN SUTHERLAND'S VISCOSITY FORMULA NASCRIN
C     FOR AIR.                                                       NASCRIN
      CVIS=1.458E-6                                                  NASCRIN
      UF=FM*(GAMA*RGAS*TF)**.5                                       NASCRIN
      ROF=PF/RGAS/TF                                                 NASCRIN
      SHF=GAMA*RGAS*TF/(GAMA-1.)                                     NASCRIN
      HF=SHF+UF*UF/2.                                                NASCRIN
C     ****************                                               NASCRIN
C     GEOMETRY INPUT AND METRIC COEFFICIENTS CALCULATIONS.           NASCRIN
C                                                                    NASCRIN
C     DEFINE IMET=0 IF METRIC COEFFICIENTS NEED NOT BE PRINTED.      NASCRIN
C     IMET=1 IF METRIC COEFFICIENTS ARE TO BE PRINTED.               NASCRIN
C     BETA=STRETCHING FACTOR.  IT SHOULD BE GREATER THAN 1.          NASCRIN
      IMET=1                                                         NASCRIN
      BETA=1.005                                                     NASCRIN
      MM=0                                                           NASCRIN
      IF(NSTRUT.EQ.0)MS=M1                                           NASCRIN
      CALL START(MM,SWEEP)                                           NASCRIN
      CALL XY(1,MS,BETA)                                             NASCRIN
      IF(NSTRUT.EQ.0)GO TO 500                                       NASCRIN
      MM=1                                                           NASCRIN
      DO 10 NN=NS1,NS2                                               NASCRIN
      N=NN-NS1+1                                                     NASCRIN
      XS(N)=X(MS,NN)                                                 NASCRIN
      YS(N)=Y(MS,NN)                                                 NASCRIN
      XSETA(N)=XETA(MS,NN)                                           NASCRIN
      YSETA(N)=YETA(MS,NN)                                           NASCRIN
      XSXI(N)=XXI(MS,NN)                                             NASCRIN
   10 YSXI(N)=YXI(MS,NN)                                             NASCRIN
      CALL START(MM,SWEEP)                                           NASCRIN
      CALL XY(MS,M1,BETA)                                            NASCRIN
      DO 20 N=1,NS1M1                                                NASCRIN
      YETA(MS,N)=(Y(MS+1,N)-Y(MS-1,N))/2.                            NASCRIN
   20 XETA(MS,N)=(X(MS+1,N)-X(MS-1,N))/2.                            NASCRIN
      DO 30 N=NS2P1,N1                                               NASCRIN
      YETA(MS,N)=(Y(MS+1,N)-Y(MS-1,N))/2.                            NASCRIN
   30 XETA(MS,N)=(X(MS+1,N)-X(MS-1,N))/2.                            NASCRIN
      AJS(1;NS)=XSXI(1;NS)*YSETA(1;NS)-XSETA(1;NS)*YSXI(1;NS)        NASCRIN
  500 CONTINUE                                                       NASCRIN
      AJ(1,1;NXM)=XXI(1,1;NXM)*YETA(1,1;NXM)-XETA(1,1;NXM)*YXI(1,1;NXM) NASCRIN
      IF(IMET.EQ.0)GO TO 45                                          NASCRIN
      DO 40 N=1,N1                                                   NASCRIN
      WRITE(6,1100)                                                  NASCRIN
      DO 40 MM=1,M1                                                  NASCRIN
      M=M1-MM+1                                                      NASCRIN
   40 WRITE(6,1200)N,M,X(M,N),Y(M,N),XXI(M,N),XETA(M,N),YXI(M,N),YETA(M,NASCRIN
     1N),AJ(M,N)                                                     NASCRIN
      IF(NSTRUT.EQ.0)GO TO 45                                        NASCRIN
      M=MS                                                           NASCRIN
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      WRITE(6,1100)                                                     NASCRIN
      WRITE(6,1200)(N,M,XS(N),YS(N),XSXI(N),XSETA(N),YSXI(N),YSETA(N),AJNASCRIN
     1S(N),N=1,NS)                                                      NASCRIN
 1100  FORMAT(/,3X,'N',3X,'M',10X,'X',10X,'Y',8X,'XXI',7X,'XETA',8X,    NASCRIN
     1'YXI',7X,'YETA',9X,'AJ',/)                                        NASCRIN
 1200  FORMAT(2X,2I3,7F11.8)                                            NASCRIN
 45   CONTINUE                                                          NASCRIN
C     ********************                                              NASCRIN
C     INTERVAL VECTOR.                                                  NASCRIN
      INT(1;N1)=Q8VINTL(1,M1;INT(1;N1))                                 NASCRIN
      LKK=0                                                             NASCRIN
      CCIMPY=1.                                                         NASCRIN
      FDTL=1.                                                           NASCRIN
      FDT=1.                                                            NASCRIN
      CCP=.5                                                            NASCRIN
 1000 CONTINUE                                                          NASCRIN
      LKK=LKK+1                                                         NASCRIN
      CCT=CCP                                                           NASCRIN
      IF(LKK.EQ.2)STOP                                                  NASCRIN
      LK=1                                                              NASCRIN
      DO 50 I=1,4                                                       NASCRIN
      BDAJS(1,I;N1)=0.                                                  NASCRIN
      BDAU(1,I;N1)=0.                                                   NASCRIN
      DAU(1,1,I;NXM)=0.                                                 NASCRIN
 50   CONTINUE                                                          NASCRIN
      VIST(1,1;NXM)=0.                                                  NASCRIN
      VISL(1,1;NXM)=0.                                                  NASCRIN
      VIS(1,1;NXM)=0.                                                   NASCRIN
      VISS(1;N1)=0.                                                     NASCRIN
C     TIMEL IS THE TIME REQUIRED BY THE FREE STREAM TO TRAVEL 3 TIMES   NASCRIN
C     OVER THE LENGTH OF THE FLOW DOMAIN.                               NASCRIN
      TIMEL=3.*X(1,N1)/UF                                               NASCRIN
      TIME=0.                                                           NASCRIN
      L=0                                                               NASCRIN
      IF(NFLOW.EQ.0) CALL INVICID(SWEEP)                                NASCRIN
      IF(NFLOW.NE.0) CALL VISCOUS(SWEEP)                                NASCRIN
      IF(LK.EQ.2) GO TO 1000                                            NASCRIN
      STOP                                                              NASCRIN
      END                                                               NASCRIN
      SUBROUTINE START(MM,SWEEP)                                        START
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 START
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                              START
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3   START
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                      START
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),                START
     1 XETA(61,55),YETA(61,55),AJ(61,55)                                START
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),              START
     1 YSETA(55),AJS(55)                                                START
C     FOR MM=0, THIS SUBROUTINE DESCRIBES THE X,Y COORDINATES OF THE    START
C     LOWER BOUNDARY AND THE MESH LINES PASSING THROUGH THE LOWER SURFACSTART
C     OF THE STRUT.  FOR MM=1, IT DESCRIBES THE COORDINATES OF THE      START
C     MESH LINE PASSING THROUGH THE UPPER SURFACE OF THE STRUT AND THE  START
C     UPPER BOUNDARY.  IF THERE IS  NO STRUT IN THE FLOWFIELD, THEN IT  START
C     DESCRIBES THE COORDINATES OF UPPER AND LOWER BOUNDARIES.          START
      PI=4.*ATAN(1.)                                                    START
      SW=SWEEP*PI/180.                                                  START
C    *****************                                                  START
C                                                                       START
C DESCRIBE X(1,N), X(M1,N), Y(1,N),Y(M1,N), FOR N=1 TO N1               START
C AND, IF MM=1, DESCRIBE                                                START
C          X(MS,N), Y(MS,N)                                             START
C                                                                       START
C  FOR QUASI-THREE-DIMENSTIONAL CALCULATIONS, PROVIDE THE GEOMETRY IN   START
C  A PLANE NORMAL TO THE SIDEWALL SWEEP.                                START
C IF IN INCHES, MULTIPLY BY .0254 TO GET METRIC UNITS                   START
C     *****************                                                 START
C     THE GEOMETRY GIVEN BELOW IS IN A PLANE NORMAL TO SWEEP LINE.      START
C     SWEEP ANGLE IS 33 DEGREES.                                        START
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      TANC1=TAN(6.*PI/180.)                                              START
      TANC2=TAN(7.5*PI/180.)                                             START
      TANC3=TAN(6.271178*PI/180.)                                        START
      X(1,1)=0.                                                          START
      DO 1 N=2,6                                                         START
    1 X(1,N)=X(1,N-1)+.005                                               START
      X(1,7)=X(1,6)+.0045                                                START
      X(1,8)=X(1,7)+.004                                                 START
      X(1,9)=X(1,8)+.0035                                                START
      X(1,10)=X(1,9)+.003                                                START
      DO 2 N=11,N1                                                       START
    2 X(1,N)=X(1,N-1)+.0025                                              START
      DX=.0025                                                           START
C     ******************                                                 START
      IF(MM.EQ.1)GO TO 300                                               START
C     ******************                                                 START
      DO 3 N=1,N1                                                        START
      X(MS,N)=X(1,N)                                                     START
      Y(1,N)=0.                                                          START
    3 Y(MS,N)=.018                                                       START
      DO 4 N=25,34                                                       START
    4 Y(1,N)=Y(1,N-1)+DX*TANC2                                           START
      DO 5 N=35,43                                                       START
    5 Y(1,N)=Y(1,N-1)-DX*TANC2                                           START
      DO 6 N=17,34                                                       START
    6 Y(MS,N)=Y(MS,N-1)-DX*TANC2                                         START
      DO 7 N=35,46                                                       START
    7 Y(MS,N)=Y(MS,N-1)+DX*TANC3                                         START
      DY=(Y(MS,46)-.013)/.0225                                           START
      DO 8 N=47,N1                                                       START
    8 Y(MS,N)=Y(MS,N-1)-DX*DY                                            START
C     ******************                                                 START
      IF(MM.EQ.0)RETURN                                                  START
C     ******************                                                 START
  300 CONTINUE                                                           START
      Y(M1,1)=.04                                                        START
      Y(M1,2)=.04                                                        START
      DO 10 N=1,N1                                                       START
      X(M1,N)=X(1,N)                                                     START
      X(MS,N)=X(1,N)                                                     START
   10 Y(MS,N)=.018                                                       START
      DO 11 N=3,N1                                                       START
   11 Y(M1,N)=Y(M1,N-1)-(X(M1,N)-X(M1,N-1))*TANC1                        START
      DO 12 N=37,46                                                      START
   12 Y(MS,N)=Y(MS,N-1)-DX*TANC1                                         START
      DY=(Y(MS,46)-.013)/.0225                                           START
      DO 13 N=47,N1                                                      START
   13 Y(MS,N)=Y(MS,N-1)-DX*DY                                            START
C                                                                        START
      RETURN                                                             START
      END                                                                START
      SUBROUTINE TURB                                                    TURB
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1  TURB
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                               TURB
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3    TURB
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                       TURB
      CALL VORT                                                          TURB
C                                                                        TURB
C************************************************************************TURB
C IF NFLOW=2 WAS SPECIFIED, EDDY VISCOSITY IS CALCULATED USING CALLS TO  TURB
C SUBROUTINE EDDY.                                                       TURB
C                                                                        TURB
C SUBROUTINE EDDY HAS SIX PARAMETERS:  NNX1,NNX2,NY1,NY2,NWALL,&NSTR.    TURB
C   NNX1,NNX2 AND NY1,NY2 ARE THE GRID NUMBERS IN THE X AND Y DIRECTIONSTURB
C            RESPECTIVELY FOR THE FLOW DOMAIN BEING CONSIDERED.          TURB
C   NWALL=1 WHEN THERE IS ONLY ONE WALL (I.E., A WALL AT NY2)            TURB
C   NWALL=2 WHEN THERE ARE TWO WALLS (I.E., WALLS AT BOTH NY1 AND NY2).  TURB
C   NSTR=1 FOR THE REGION IN WHICH THE LOWER SURFACE OF THE STRUT FORMS  TURB
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C             THE UPPER WALL OF THE FLOW DOMAIN (NY2=MS1).                      TURB
C   NSTR=0 OTHERWISE                                                           TURB
C                                                                              TURB
C USE AS MANY CALLS TO SUBROUTINE EDDY AS NECESSARY TO DEFINE ENTIRE REGTURB
C SEE EXAMPLES IN THE USER'S MANUAL FOR FURTHER CLARIFICATION.                 TURB
C************************************************************************TURB
C                                                                              TURB
      CALL EDDY(2,15,1,M1,1,0)                                                 TURB
      CALL EDDY(16,46,MS,M1,2,0)                                               TURB
      CALL EDDY(16,23,1,MS1,1,1)                                               TURB
      CALL EDDY(24,46,1,MS1,2,1)                                               TURB
      CALL EDDY(47,N1,1,M1,1,0)                                                TURB
      RETURN                                                                   TURB
      END                                                                      TURB
      SUBROUTINE XY(ETAMN,ETAMX,BETA)                                          XY
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 XY
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                                     XY
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3        XY
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                             XY
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),                       XY
     1 XETA(61,55),YETA(61,55),AJ(61,55)                                       XY
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),                     XY
     1 YSETA(55),AJS(55)                                                       XY
      DIMENSION ETAB(61),ETAD(61)                                              XY
      INTEGER ETAMX,ETAMN                                                      XY
      B=ALOG((BETA+1.)/(BETA-1.))                                              XY
      NETA=ETAMX-ETAMN                                                         XY
      DO 10 M=ETAMN,ETAMX                                                      XY
      A=(2.*(M-ETAMN)/NETA-1.)*B                                               XY
      EXPA=EXP(A)                                                              XY
      ETAY=((BETA+1.)*EXPA-BETA+1.)/(1.+EXPA)                                  XY
      ETAB(M)=ETAY*NETA/2.+ETAMN                                               XY
   10 ETAD(M)=2.*B*BETA*EXPA/(1.+EXPA)**2                                      XY
      DO 15 N=1,N1                                                             XY
      DO 15 M=ETAMN,ETAMX                                                      XY
      X(M,N)=(X(ETAMX,N)*(ETAB(M)-ETAMN)+X(ETAMN,N)*(ETAMX-ETAB(M)))/        XY
     1NETA                                                                     XY
      Y(M,N)=(Y(ETAMX,N)*(ETAB(M)-ETAMN)+Y(ETAMN,N)*(ETAMX-ETAB(M)))/        XY
     1NETA                                                                     XY
      XETA(M,N)=(X(ETAMX,N)-X(ETAMN,N))*ETAD(M)/NETA                           XY
   15 YETA(M,N)=(Y(ETAMX,N)-Y(ETAMN,N))*ETAD(M)/NETA                           XY
      DO 20 N=2,N11                                                            XY
      DO 20 M=ETAMN,ETAMX                                                      XY
      XXI(M,N)=(X(M,N+1)-X(M,N-1))/2.                                          XY
   20 YXI(M,N)=(Y(M,N+1)-Y(M,N-1))/2.                                          XY
      DO 30 M=ETAMN,ETAMX                                                      XY
      XXI(M,1)=X(M,2)-X(M,1)                                                   XY
      YXI(M,1)=Y(M,2)-Y(M,1)                                                   XY
      XXI(M,N1)=X(M,N1)-X(M,N11)                                               XY
   30 YXI(M,N1)=Y(M,N1)-Y(M,N11)                                               XY
      RETURN                                                                   XY
      END                                                                      XY
      SUBROUTINE VISCOUS(SWEEP)                                                VISCOUS
      BIT BI                                                                   VISCOUS
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 VISCOUS
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                                     VISCOUS
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3        VISCOUS
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                             VISCOUS
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),                 VISCOUS
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                               VISCOUS
     2 PS(55),TS(55),SHS(55),HS(55)                                            VISCOUS
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)                    VISCOUS
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),                VISCOUS
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)                VISCOUS
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)               VISCOUS
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)                       VISCOUS
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),                       VISCOUS
     1 XETA(61,55),YETA(61,55),AJ(61,55)                                       VISCOUS
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      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),             VISCOUS
     1 YSETA(55),AJS(55)                                                VISCOUS
      COMMON/F9/INT(55),TE1(55),TE2(55),TE3(55),TE4(55)                 VISCOUS
      COMMON/F10/DT(61,55),DTM                                          VISCOUS
      COMMON/F11/ERRO(61,55),B1(61,55)                                  VISCOUS
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,    VISCOUS
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG                                  VISCOUS
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF        VISCOUS
      COMMON/F14/DAU(61,55,4),BDAU(55,4),BDAUS(55,4),TI(55,5),          VISCOUS
     1CCIMPY,GM1,GM2,GM3,GM4,GM5                                        VISCOUS
C                                                                       VISCOUS
C     INITIAL GUESS                                                     VISCOUS
C                                                                       VISCOUS
      U(1,1;NXM)=UF                                                     VISCOUS
      V(1,1;NXM)=0.                                                     VISCOUS
      T(1,1;NXM)=TF                                                     VISCOUS
      SH(1,1;NXM)=SHF                                                   VISCOUS
       H(1,1;NXM)=HF                                                    VISCOUS
      P(1,1;NXM)=PF                                                     VISCOUS
      RO(1,1;NXM)=P(1,1;NXM)/RGAS/T(1,1;NXM)                            VISCOUS
      IF(ILT.EQ.1)GO TO 2                                               VISCOUS
      READ(LFI,561) L,TIME                                              VISCOUS
      DO 3 N=1,N1                                                       VISCOUS
       READ(LFI,560)(X(M,N),Y(M,N),U(M,N),V(M,N),P(M,N),T(M,N),RO(M,N), VISCOUS
     1SH(M,N),H(M,N),VIST(M,N),M=1,M1)                                  VISCOUS
 3    CONTINUE                                                          VISCOUS
      LMAX=LMAX+L                                                       VISCOUS
      IF(NSTRUT.EQ.0)GO TO 2                                            VISCOUS
       READ(LFI,560)(XS(N),YS(N),US(N),VS(N),PS(N),TS(N),ROS(N),SHS(N), VISCOUS
     1HS(N),VISS(N),N=1,NS)                                             VISCOUS
 2    CONTINUE                                                          VISCOUS
      L=L+1                                                             VISCOUS
      CALL BOUND                                                        VISCOUS
 1    CONTINUE                                                          VISCOUS
      LSTEP=1                                                           VISCOUS
      ERRO(1,1;NXM)=RO(1,1;NXM)                                         VISCOUS
      QX(2,2;NXM4)=GAMA*P(2,2;NXM4)/RO(2,2;NXM4)                        VISCOUS
      QX(2,2;NXM4)=VSQRT(QX(2,2;NXM4);QX(2,2;NXM4))                     VISCOUS
      DT(2,2;NXM4)=FDT*YETA(2,2;NXM4)          /(VABS(V(2,2;NXM4);      VISCOUS
     1QY(2,2;NXM4))+QX(2,2;NXM4))                                       VISCOUS
      DTM=Q8SMIN(DT(2,2;NXM4))                                          VISCOUS
      DTML=FDTL*DTM                                                     VISCOUS
      B1(2,2;NXM4)=DT(2,2;NXM4).GT.DTML                                 VISCOUS
      DT(2,2;NXM4)=Q8VCTRL(DTML,B1(2,2;NXM4);DT(2,2;NXM4))              VISCOUS
      TIME=TIME+DTM                                                     VISCOUS
      CALL DVISCP                                                       VISCOUS
      CALL VEC1                                                         VISCOUS
      CALL DAMPP                                                        VISCOUS
C                                                                       VISCOUS
C     PREDICTOR STEP WITH  FORWARD DIFFERENCING.                        VISCOUS
C                                                                       VISCOUS
      IF(FDT.GT.1.)GO TO 10                                             VISCOUS
      DO 100 I=1,4                                                      VISCOUS
      AU1(2,2,I;NXM4)=AU(2,2,I;NXM4)-DT(2,2;NXM4)*((AM(2,3,I;NXM4)-AM(2,VISCOUS
     12,I;NXM4))+(AN(3,2,I;NXM4)-AN(2,2,I;NXM4)))                       VISCOUS
      IF(NSTRUT.EQ.0)GO TO 100                                          VISCOUS
      DO 105 N=1,NS                                                     VISCOUS
      NN=N+NS1-1                                                        VISCOUS
      AU1(MS1,NN,I)=AU(MS1,NN,I)-DT(MS1,NN)*(AM(MS1,NN+1,I)-AM(MS1,NN,I)VISCOUS
     1+ANS(N,I)-AN(MS1,NN,I))                                           VISCOUS
 105  CONTINUE                                                          VISCOUS
 100  CONTINUE                                                          VISCOUS
      CALL VEC2                                                         VISCOUS
      CALL BOUND                                                        VISCOUS
      GO TO 20                                                          VISCOUS
 10   CONTINUE                                                          VISCOUS
      DO 15 I=1,4                                                       VISCOUS
      DAU(2,2,I;NXM4)=-DT(2,2;NXM4)*(AM(2,3,I;NXM4)-AM(2,2,I;NXM4)+     VISCOUS
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     1AN(3,2,I;NXM4)-AN(2,2,I;NXM4))/AJ(2,2;NXM4)
      IF(NSTRUT.EQ.0)GO TO 15
      DO 16 N=1,NS
      NN=N+NS1-1
      DAU(MS1,NN,I)=-DT(MS1,NN)*(AM(MS1,NN+1,I)-AM(MS1,NN,I)+ANS(N,I)-
     1AN(MS1,NN,I))/AJ(MS1,NN)
   16 CONTINUE
   15 CONTINUE
      IADD=1
      CALL IMPY(IADD)
      DO 17 I=1,4
   17 AU1(2,2,I;NXM4)=AU(2,2,I;NXM4)+DAU(2,2,I;NXM4)*AJ(2,2;NXM4)
C      SUBROUTINE BOUND IS CALLED IN VECIM2.
      CALL VECIM2(IADD)
   20 CONTINUE
      IF(LK.EQ.2)RETURN
      DO 160 I=1,4
      AU1(2,2,I;NXM4)=AU(2,2,I;NXM4)+AU1(2,2,I;NXM4)
  160 CONTINUE
      CALL DVISCC
      CALL VEC1
      CALL DAMPC
C
C     CORRECTOR STEP WITH BACKWORD DIFFERENCING
C
      IF(FDT.GT.1.)GO TO 30
      DO 210 I=1,4
      AU1(2,2,I;NXM4)=0.5*(AU1(2,2,I;NXM4)-DT(2,2;NXM4)*((AM(2,2,I;NXM4)
     1-AM(2,1,I;NXM4))+(AN(2,2,I;NXM4)-AN(1,2,I;NXM4))))
  210 CONTINUE
      CALL VEC2
      CALL BOUND
      GO TO 40
   30 CONTINUE
      DO 35 I=1,4
      DAU(2,2,I;NXM4)=-DT(2,2;NXM4)*(AM(2,2,I;NXM4)-AM(2,1,I;NXM4)+
     1AN(2,2,I;NXM4)-AN(1,2,I;NXM4))/AJ(2,2;NXM4)
   35 CONTINUE
      IADD=0
      CALL IMPY(IADD)
      DO 36 I=1,4
   36 AU1(2,2,I;NXM4)=.5*(AU1(2,2,I;NXM4)+DAU(2,2,I;NXM4)*AJ(2,2;NXM4))
      IADD=1
C     SUBROUTINE BOUND IS CALLED IN VECIM2.
      CALL VECIM2(IADD)
   40 CONTINUE
      IF(LK.EQ.2)RETURN
      L=L+1
      LSTEP=2
      QX(2,2;NXM4)=GAMA*P(2,2;NXM4)/RO(2,2;NXM4)
      QX(2,2;NXM4)=VSQRT(QX(2,2;NXM4);QX(2,2;NXM4))
      DT(2,2;NXM4)=FDT*YETA(2,2;NXM4)           /(VABS(V(2,2;NXM4);
     1QY(2,2;NXM4))+QX(2,2;NXM4))
      DTM=Q8SMIN(DT(2,2;NXM4))
      DTML=FDTL*DTM
      B1(2,2;NXM4)=DT(2,2;NXM4).GT.DTML
      DT(2,2;NXM4)=Q8VCTRL(DTML,B1(2,2;NXM4);DT(2,2;NXM4))
      TIME=TIME+DTM
      CALL DVISCC
      CALL VEC1
      CALL DAMPC
C
C     PREDICTOR STEP WITH BACKWARD DIFFERENCING.
C
      IF(FDT.GT.1.)GO TO 50
      DO 110 I=1,4
      AU1(2,2,I;NXM4)=AU(2,2,I;NXM4)-DT(2,2;NXM4)*((AM(2,2,I;NXM4)-AM(2,
     11,I;NXM4))+(AN(2,2,I;NXM4)-AN(1,2,I;NXM4)))
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 110  CONTINUE                                                        VISCOUS
      CALL VEC2                                                       VISCOUS
      CALL BOUND                                                      VISCOUS
      GO TO 60                                                        VISCOUS
  50  CONTINUE                                                        VISCOUS
      DO 55 I=1,4                                                     VISCOUS
      DAU(2,2,I;NXM4)=-DT(2,2;NXM4)*(AM(2,2,1;NXM4)-AM(2,1,I;NXM4)+   VISCOUS
     1AN(2,2,I;NXM4)-AN(1,2,I;NXM4))/AJ(2,2;NXM4)                     VISCOUS
  55  CONTINUE                                                        VISCOUS
      IADD=0                                                          VISCOUS
      CALL IMPY(IADD)                                                 VISCOUS
      DO 56 I=1,4                                                     VISCOUS
      AU1(2,2,I;NXM4)=AJ(2,2,I;NXM4)+DAU(2,2,I;NXM4)*AJ(2,2;NXM4)     VISCOUS
  56  CONTINUE                                                        VISCOUS
C      SUBROUTINE BOUND IS CALLED IN VECIM2.                          VISCOUS
      CALL VECIM2(IADD)                                               VISCOUS
  60  CONTINUE                                                        VISCOUS
      IF(LK.EQ.2)RETURN                                               VISCOUS
      DO 165 I=1,4                                                    VISCOUS
      AU1(2,2,I;NXM4)=AU(2,2,I;NXM4)+AU1(2,2,I;NXM4)                  VISCOUS
      IF(NSTRUT.EQ.0)GO TO 165                                        VISCOUS
      DO 150 N=1,NS                                                   VISCOUS
      NN=N+NS1-1                                                      VISCOUS
 150  AUS1(N,I)=AU1(MS1,NN,I)                                         VISCOUS
 165   CONTINUE                                                       VISCOUS
      CALL DVISCP                                                     VISCOUS
      CALL VEC1                                                       VISCOUS
      CALL DAMPP                                                      VISCOUS
C                                                                     VISCOUS
C     CORRECTOR STEP WITH FORWARD DIFFERENCING                        VISCOUS
C                                                                     VISCOUS
      IF(FDT.GT.1.)GO TO 70                                           VISCOUS
      DO 215 I=1,4                                                    VISCOUS
      AU1(2,2,I;NXM4)=0.5*(AU1(2,2,I;NXM4)-DT(2,2;NXM4)*((AM(2,3,I;NXM4)VISCOUS
     1-AM(2,2,I;NXM4))+(AN(3,2,I;NXM4)-AN(2,2,I;NXM4))))              VISCOUS
      IF(NSTRUT.EQ.0)GO TO 215                                        VISCOUS
      DO 120 N=1,NS                                                   VISCOUS
      NN=N+NS1-1                                                      VISCOUS
      AU1(MS1,NN,I)=0.5*(AUS1(N,I)-DT(MS1,NN)*(AM(MS1,NN+1,I)-AM(MS1,NN,VISCOUS
     1I)+ANS(N,I)-AN(MS1,NN,I)))                                      VISCOUS
 120  CONTINUE                                                        VISCOUS
 215  CONTINUE                                                        VISCOUS
      CALL VEC2                                                       VISCOUS
      CALL BOUND                                                      VISCOUS
      GO TO 80                                                        VISCOUS
  70  CONTINUE                                                        VISCOUS
      DO 75 I=1,4                                                     VISCOUS
      DAU(2,2,I;NXM4)=-DT(2,2;NXM4)*(AM(2,3,1;NXM4)-AM(2,2,I;NXM4)+   VISCOUS
     1AN(3,2,I;NXM4)-AN(2,2,I;NXM4))/AJ(2,2;NXM4)                     VISCOUS
      IF(NSTRUT.EQ.0)GO TO 75                                         VISCOUS
      DO 76 N=1,NS                                                    VISCOUS
      NN=N+NS1-1                                                      VISCOUS
      DAU(MS1,NN,I)=-DT(MS1,NN)*(AM(MS1,NN+1,I)-AM(MS1,NN,I)+         VISCOUS
     1ANS(N,I)-AN(MS1,NN,I))/AJ(MS1,NN)                               VISCOUS
  76  CONTINUE                                                        VISCOUS
  75  CONTINUE                                                        VISCOUS
      IADD=1                                                          VISCOUS
      CALL IMPY(IADD)                                                 VISCOUS
      DO 77 I=1,4                                                     VISCOUS
  77  AU1(2,2,I;NXM4)=.5*(AU1(2,2,I;NXM4)+DAU(2,2,I;NXM4)*AJ(2,2;NXM4)) VISCOUS
      IADD=0                                                          VISCOUS
C     SUBROUTINE BOUND IS CALLED IN VECIM2.                           VISCOUS
      CALL VECIM2(IADD)                                               VISCOUS
  80  CONTINUE                                                        VISCOUS
      IF(LK.EQ.2)RETURN                                               VISCOUS
      IF(NFLOW.NE.2)GO TO 216                                         VISCOUS
      LL=L/20                                                         VISCOUS
      LL=LL*20                                                        VISCOUS
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      IF(LL.NE.L)GO TO 216                                              VISCOUS
      CALL TURB                                                         VISCOUS
 216   CONTINUE                                                         VISCOUS
      ERRO(1,1;NXM)=(RO(1,1;NXM)-ERRO(1,1;NXM))/ERRO(1,1;NXM)/FDT/LSTEP VISCOUS
      ERRO(1,1;NXM)=VABS(ERRO(1,1;NXM);ERRO(1,1;NXM))                   VISCOUS
      ERRMX=Q8SMAX(ERRO(1,1;NXM))                                       VISCOUS
      IF(ERRMX.LE.CRIT)GO TO 217                                        VISCOUS
      IF(TIME.GT.TIMEL)GO TO 217                                        VISCOUS
      LL=L/50                                                           VISCOUS
      LL=LL*50                                                          VISCOUS
      IF(LL.NE.L)GO TO 220                                              VISCOUS
      SIGX(1,1;NXM)=ERRO(1,1;NXM)*ERRO(1,1;NXM)                         VISCOUS
      ERRAVG=Q8SSUM(SIGX(1,1;NXM))                                      VISCOUS
      ERRAVG=SQRT(ERRAVG)/NXM                                           VISCOUS
      IF(ERRAVG.LE.CRITAVG) GO TO 217                                   VISCOUS
      WRITE(6,510)L,ERRMX,ERRAVG                                        VISCOUS
 510  FORMAT(/,10X,'L=',I5,10X,'MAX.ERROR=',E12.5,10X,                  VISCOUS
     1'MEAN SQRT ERROR=',E12.5)                                         VISCOUS
      LL=L/LW                                                           VISCOUS
      LL=LL*LW                                                          VISCOUS
      IF(LL.NE.L)GO TO 220                                              VISCOUS
 217  CONTINUE                                                          VISCOUS
      CALL PRINT                                                        VISCOUS
      CALL SPILL(SWEEP)                                                 VISCOUS
      IF(ERRAVG.LE.CRITAVG) WRITE(6,600)                                VISCOUS
      IF(ERRAVG.LE.CRITAVG) GO TO 218                                   VISCOUS
      IF(TIME.GT.TIMEL) WRITE(6,610)                                    VISCOUS
      IF(TIME.GT.TIMEL) GO TO 218                                       VISCOUS
      IF(ERRMX.LE.CRIT) WRITE(6,620)                                    VISCOUS
      IF(ERRMX.LE.CRIT)GO TO 218                                        VISCOUS
 220   CONTINUE                                                         VISCOUS
      L=L+1                                                             VISCOUS
      IF(L.LE.LMAX)GO TO 1                                              VISCOUS
      L=L-1                                                             VISCOUS
      WRITE(6,630)                                                      VISCOUS
 218  CONTINUE                                                          VISCOUS
      REWIND LFO                                                        VISCOUS
      WRITE(LFO,561) L,TIME                                             VISCOUS
      DO 300 N=1,N1                                                     VISCOUS
      WRITE(LFO,560)(X(M,N),Y(M,N),U(M,N),V(M,N),P(M,N),T(M,N),RO(M,N), VISCOUS
     1SH(M,N),H(M,N),VIST(M,N),M=1,M1)                                  VISCOUS
 300  CONTINUE                                                          VISCOUS
      IF(NSTRUT.EQ.0)GO TO 310                                          VISCOUS
      WRITE(LFO,560)(XS(N),YS(N),US(N),VS(N),PS(N),TS(N),ROS(N),SHS(N), VISCOUS
     1HS(N),VISS(N),N=1,NS)                                             VISCOUS
 310  CONTINUE                                                          VISCOUS
 560  FORMAT(1X, 2F9.6,2F12.5,F14.5,F13.5,F11.5,F14.5,F15.6,F10.6)      VISCOUS
 561 FORMAT(1X,I6,2X,E15.7)                                             VISCOUS
 600  FORMAT(//,20X,'PROGRAM TERMINATED ON MEAN SQRT ERROR CRITERION')  VISCOUS
 610 FORMAT(//,20X,'PROGRAM TERMINATED ON PHYSICAL TIME ',              VISCOUS
     1              'CONVERGENCE CRITERION')                            VISCOUS
 620 FORMAT(//,20X,'PROGRAM TERMINATED ON LOCAL ERROR CRITERION')       VISCOUS
 630 FORMAT(//,20X,'PROGRAM TERMINATED ON LMAX')                        VISCOUS
      RETURN                                                            VISCOUS
      END                                                               VISCOUS
      SUBROUTINE INVICID(SWEEP)                                         INVICID
      BIT B1                                                            INVICID
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 INVICID
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                              INVICID
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3   INVICID
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                      INVICID
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),          INVICID
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                        INVICID
     2 PS(55),TS(55),SHS(55),HS(55)                                     INVICID
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)             INVICID
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),         INVICID
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)         INVICID
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)        INVICID
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      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),
     1 YSETA(55),AJS(55)
      COMMON/F9/INT(55),TE1(55),TE2(55),TE3(55),TE4(55)
      COMMON/F10/DT(61,55),DTM
      COMMON/F11/ERRO(61,55),B1(61,55)
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
C
C     INITIAL GUESS
C
      V(1,1;NXM)=YXI(1,1;NXM)/XXI(1,1;NXM)*UF
      U(1,1;NXM)=UF*UF-V(1,1;NXM)*V(1,1;NXM)
      U(1,1;NXM)=VSQRT(U(1,1;NXM);U(1,1;NXM))
      T(1,1;NXM)=TF
      P(1,1;NXM)=PF
      RO(1,1;NXM)=ROF
      SH(1,1;NXM)=SHF
      H(1,1;NXM)=HF
      IF(NSTRUT.EQ.0) GO TO 4
      VS(1;NS)=YSXI(1;NS)/XSXI(1;NS)*UF
      US(1;NS)=UF*UF-VS(1;NS)*VS(1;NS)
      US(1;NS)=VSQRT(US(1;NS);US(1;NS))
      PS(1;NS)=PF
      TS(1;NS)=TF
      SHS(1;NS)=SHF
      ROS(1;NS)=ROF
      HS(1;NS)=HF
    4 CONTINUE
      IF(ILT.EQ.1)GO TO 2
      READ(LFI,561) L,TIME
      DO 3 N=1,N1
       READ(LFI,560)(X(M,N),Y(M,N),U(M,N),V(M,N),P(M,N),T(M,N),RO(M,N),
     1SH(M,N),H(M,N),VIST(M,N),M=1,M1)
    3 CONTINUE
      LMAX=LMAX+L
      IF(NSTRUT.EQ.0)GO TO 2
       READ(LFI,560)(XS(N),YS(N),US(N),VS(N),PS(N),TS(N),ROS(N),SHS(N),
     1HS(N),VISS(N),N=1,NS)
    2 CONTINUE
      L=L+1
      CALL IBOUND
    1 CONTINUE
      LSTEP=1
      ERRO(1,1;NXM)=RO(1,1;NXM)
      QX(2,2;NXM4)=GAMA*P(2,2;NXM4)/RO(2,2;NXM4)
      QX(2,2;NXM4)=VSQRT(QX(2,2;NXM4);QX(2,2;NXM4))
      DT(2,2;NXM4)=FDT*YETA(2,2;NXM4)          /(VABS(V(2,2;NXM4);
     1QY(2,2;NXM4))+QX(2,2;NXM4))
      DTM=Q8SMIN(DT(2,2;NXM4))
      DTML=FDTL*DTM
      B1(2,2;NXM4)=DT(2,2;NXM4).GT.DTML
      DT(2,2;NXM4)=Q8VCTRL(DTML,B1(2,2;NXM4);DT(2,2;NXM4))
      TIME=TIME+DTM
      CALL IVECI
      CALL DAMPP
C
C     PREDICTOR STEP WITH  FORWARD DIFFERENCING.
C
      DO 100 I=1,4
      AU1(2,2,I;NXM4)=AU(2,2,I;NXM4)-DT(2,2;NXM4)*((AM(2,3,I;NXM4)-AM(2,
     12,I;NXM4))+(AN(3,2,I;NXM4)-AN(2,2,I;NXM4)))
      IF(NSTRUT.EQ.0)GO TO 100
      DO 105 N=1,NS
      NN=N+NS1-1
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      AU1(MS1,NN,I)=AU(MS1,NN,I)-DT(MS1,NN)*(AM(MS1,NN+1,I)-AM(MS1,NN,I)INVICID
     1+ANS(N,I)-AN(MS1,NN,I))                                         INVICID
  105 CONTINUE                                                        INVICID
  100 CONTINUE                                                        INVICID
      CALL VEC2                                                       INVICID
      CALL IBOUND                                                     INVICID
      IF(LK.EQ.2)RETURN                                               INVICID
      DO 160 I=1,4                                                    INVICID
      AU1(2,2,I;NXM4)=AU(2,2,I;NXM4)+AU1(2,2,I;NXM4)                  INVICID
  160 CONTINUE                                                        INVICID
      CALL IVEC1                                                      INVICID
      CALL DAMPC                                                      INVICID
C                                                                     INVICID
C     CORRECTOR STEP WITH BACKWORD DIFFERENCING                       INVICID
C                                                                     INVICID
      DO 210 I=1,4                                                    INVICID
      AU1(2,2,I;NXM4)=0.5*(AU1(2,2,I;NXM4)-DT(2,2;NXM4)*((AM(2,2,I;NXM4)INVICID
     1-AM(2,1,I;NXM4))+(AN(2,2,I;NXM4)-AN(1,2,I;NXM4))))              INVICID
  210 CONTINUE                                                        INVICID
      CALL VEC2                                                       INVICID
      CALL IBOUND                                                     INVICID
      IF(LK.EQ.2)RETURN                                               INVICID
      L=L+1                                                           INVICID
      LSTEP=2                                                         INVICID
      QX(2,2;NXM4)=GAMA*P(2,2;NXM4)/RO(2,2;NXM4)                      INVICID
      QX(2,2;NXM4)=VSQRT(QX(2,2;NXM4);QX(2,2;NXM4))                   INVICID
      DT(2,2;NXM4)=FDT*YETA(2,2;NXM4)          /(VABS(V(2,2;NXM4);    INVICID
     1QY(2,2;NXM4))+QX(2,2;NXM4))                                     INVICID
      DTM=Q8SMIN(DT(2,2;NXM4))                                        INVICID
      DTML=FDTL*DTM                                                   INVICID
      B1(2,2;NXM4)=DT(2,2;NXM4).GT.DTML                               INVICID
      DT(2,2;NXM4)=Q8VCTRL(DTML,B1(2,2;NXM4);DT(2,2;NXM4))            INVICID
      TIME=TIME+DTM                                                   INVICID
      CALL IVEC1                                                      INVICID
      CALL DAMPC                                                      INVICID
C                                                                     INVICID
C     PREDICTOR STEP WITH BACKWARD DIFFERENCING.                      INVICID
C                                                                     INVICID
      DO 110 I=1,4                                                    INVICID
      AU1(2,2,I;NXM4)=AU(2,2,I;NXM4)-DT(2,2;NXM4)*((AM(2,2,I;NXM4)-AM(2,INVICID
     11,I;NXM4))+(AN(2,2,I;NXM4)-AN(1,2,I;NXM4)))                     INVICID
  110 CONTINUE                                                        INVICID
      CALL VEC2                                                       INVICID
      CALL IBOUND                                                     INVICID
      IF(LK.EQ.2)RETURN                                               INVICID
      DO 165 I=1,4                                                    INVICID
      AU1(2,2,I;NXM4)=AU(2,2,I;NXM4)+AU1(2,2,I;NXM4)                  INVICID
      IF(NSTRUT.EQ.0)GO TO 165                                        INVICID
      DO 150 N=1,NS                                                   INVICID
      NN=N+NS1-1                                                      INVICID
  150 AUS1(N,I)=AU1(MS1,NN,I)                                         INVICID
  165  CONTINUE                                                       INVICID
      CALL IVEC1                                                      INVICID
      CALL DAMPP                                                      INVICID
C                                                                     INVICID
C     CORRECTOR STEP WITH FORWARD DIFFERENCING                        INVICID
C                                                                     INVICID
      DO 215 I=1,4                                                    INVICID
      AU1(2,2,I;NXM4)=0.5*(AU1(2,2,I;NXM4)-DT(2,2;NXM4)*((AM(2,3,I;NXM4)INVICID
     1-AM(2,2,I;NXM4))+(AN(3,2,I;NXM4)-AN(2,2,I;NXM4))))              INVICID
      IF(NSTRUT.EQ.0)GO TO 215                                        INVICID
      DO 120 N=1,NS                                                   INVICID
      NN=N+NS1-1                                                      INVICID
      AU1(MS1,NN,I)=0.5*(AUS1(N,I)-DT(MS1,NN)*(AM(MS1,NN+1,I)-AM(MS1,NN,INVICID
     1I)+ANS(N,I)-AN(MS1,NN,I)))                                      INVICID
  120 CONTINUE                                                        INVICID
  215 CONTINUE                                                        INVICID
      CALL VEC2                                                       INVICID
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      CALL IBOUND                                                       INVICID
      IF(LK.EQ.2)RETURN                                                 INVICID
      ERRO(1,1;NXM)=(RO(1,1;NXM)-ERRO(1,1;NXM))/ERRO(1,1;NXM)/FDT/LSTEP INVICID
      ERRO(1,1;NXM)=VABS(ERRO(1,1;NXM);ERRO(1,1;NXM))                   INVICID
      ERRMX=Q8SMAX(ERRO(1,1;NXM))                                       INVICID
      IF(ERRMX.LE.CRIT)GO TO 217                                        INVICID
      IF(TIME.GT.TIMEL)GO TO 217                                        INVICID
      LL=L/50                                                           INVICID
      LL=LL*50                                                          INVICID
      IF(LL.NE.L)GO TO 220                                              INVICID
      SIGX(1,1;NXM)=ERRO(1,1;NXM)*ERRO(1,1;NXM)                         INVICID
      ERRAVG=Q8SSUM(SIGX(1,1;NXM))                                      INVICID
      ERRAVG=SQRT(ERRAVG)/NXM                                           INVICID
      IF(ERRAVG.LE.CRITAVG) GO TO 217                                   INVICID
      WRITE(6,510)L,ERRMX,ERRAVG                                        INVICID
  510 FORMAT(/,10X,'L=',I5,10X,'MAX. ERROR=',E12.5,10X,                 INVICID
     1'MEAN SQRT ERROR=',E12.5)                                         INVICID
      LL=L/LW                                                           INVICID
      LL=LL*LW                                                          INVICID
      IF(LL.NE.L)GO TO 220                                              INVICID
  217 CONTINUE                                                          INVICID
      CALL PRINT                                                        INVICID
      CALL SPILL(SWEEP)                                                 INVICID
      IF(ERRAVG.LE.CRITAVG) WRITE(6,600)                                INVICID
      IF(ERRAVG.LE.CRITAVG) GO TO 218                                   INVICID
      IF(TIME.GT.TIMEL) WRITE(6,610)                                    INVICID
      IF(TIME.GT.TIMEL) GO TO 218                                       INVICID
      IF(ERRMX.LE.CRIT) WRITE(6,620)                                    INVICID
      IF(ERRMX.LE.CRIT)GO TO 218                                        INVICID
  220  CONTINUE                                                         INVICID
      L=L+1                                                             INVICID
      IF(L.LE.LMAX)GO TO 1                                              INVICID
      L=L-1                                                             INVICID
      WRITE(6,630)                                                      INVICID
  218 CONTINUE                                                          INVICID
      REWIND LFO                                                        INVICID
      WRITE(LFO,561) L,TIME                                             INVICID
      DO 300 N=1,N1                                                     INVICID
      WRITE(LFO,560)(X(M,N),Y(M,N),U(M,N),V(M,N),P(M,N),T(M,N),RO(M,N), INVICID
     1SH(M,N),H(M,N),VIST(M,N),M=1,M1)                                  INVICID
  300 CONTINUE                                                          INVICID
      IF(NSTRUT.EQ.0)GO TO 310                                          INVICID
      WRITE(LFO,560)(XS(N),YS(N),US(N),VS(N),PS(N),TS(N),ROS(N),SHS(N), INVICID
     1HS(N),VISS(N),N=1,NS)                                             INVICID
  310 CONTINUE                                                          INVICID
  560 FORMAT(1X, 2F9.6,2F12.5,F14.5,F13.5,F11.5,F14.5,F15.6,F10.6)      INVICID
  561 FORMAT(1X,I6,2X,E15.7)                                            INVICID
  600 FORMAT(//,20X,'PROGRAM TERMINATED ON MEAN SQRT ERROR CRITERION')  INVICID
  610 FORMAT(//,20X,'PROGRAM TERMINATED ON PHYSICAL TIME ',             INVICID
     1              'CONVERGENCE CRITERION')                            INVICID
  620 FORMAT(//,20X,'PROGRAM TERMINATED ON LOCAL ERROR CRITERION')      INVICID
  630 FORMAT(//,20X,'PROGRAM TERMINATED ON LMAX')                       INVICID
      RETURN                                                            INVICID
      END                                                               INVICID
      SUBROUTINE DVISCP                                                 DVISCP
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 DVISCP
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                              DVISCP
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3   DVISCP
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                      DVISCP
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),          DVISCP
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                        DVISCP
     2 PS(55),TS(55),SHS(55),HS(55)                                     DVISCP
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)             DVISCP
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),         DVISCP
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)         DVISCP
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)        DVISCP
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)                DVISCP
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),                DVISCP
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     1 XETA(61,55),YETA(61,55),AJ(61,55)                               DVISCP
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),             DVISCP
     1 YSETA(55),AJS(55)                                               DVISCP
      COMMON/F9/INT(55),TE1(55),TE2(55),TE3(55),TE4(55)                DVISCP
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF       DVISCP
      VIS(1,1;NXM)=VISL(1,1;NXM)+VIST(1,1;NXM)                         DVISCP
      NXMM=NXM-M1                                                      DVISCP
      AU(1,2,1;NXMM)=U(1,2;NXMM)-U(1,1;NXMM)                           DVISCP
      AU(1,1,1;M1)=U(1,2;M1)-U(1,1;M1)                                 DVISCP
      AU(1,2,2;NXMM)=V(1,2;NXMM)-V(1,1;NXMM)                           DVISCP
      AU(1,1,2;M1)=V(1,2;M1)-V(1,1;M1)                                 DVISCP
      AM(1,2,1;NXMM)=SH(1,2;NXMM)-SH(1,1;NXMM)                         DVISCP
      AM(1,1,1;M1)=SH(1,2;M1)-SH(1,1;M1)                               DVISCP
      AU(2,1,3;NXM1)=U(2,1;NXM1)-U(1,1;NXM1)                           DVISCP
      TE1(1;N1)=Q8VGATHR(U(1,1;NXM),INT(1;N1);TE1(1;N1))               DVISCP
      TE2(1;N1)=Q8VGATHR( U(2,1;NXM),INT(1;N1);TE2(1;N1))              DVISCP
      TE3(1;N1)=TE2(1;N1)-TE1(1;N1)                                    DVISCP
      AU(1,1,3;NXM)=Q8VSCATR(TE3(1;N1),INT(1;N1);AU(1,1,3;NXM))        DVISCP
      AU(2,1,4;NXM1)=V(2,1;NXM1)-V(1,1;NXM1)                           DVISCP
      TE1(1;N1)=Q8VGATHR(V(1,1;NXM),INT(1;N1);TE1(1;N1))               DVISCP
      TE2(1;N1)=Q8VGATHR( V(2,1;NXM),INT(1;N1);TE2(1;N1))              DVISCP
      TE3(1;N1)=TE2(1;N1)-TE1(1;N1)                                    DVISCP
      AU(1,1,4;NXM)=Q8VSCATR(TE3(1;N1),INT(1;N1);AU(1,1,4;NXM))        DVISCP
      AM(2,1,2;NXM1)=SH(2,1;NXM1)-SH(1,1;NXM1)                         DVISCP
      TE1(1;N1)=Q8VGATHR(SH(1,1;NXM),INT(1;N1);TE1(1;N1))              DVISCP
      TE2(1;N1)=Q8VGATHR(SH(2,1;NXM),INT(1;N1);TE2(1;N1))              DVISCP
      TE3(1;N1)=TE2(1;N1)-TE1(1;N1)                                    DVISCP
      AM(1,1,2;NXM)=Q8VSCATR(TE3(1;N1),INT(1;N1);AM(1,1,2;NXM))        DVISCP
      IF(NSTRUT.EQ.0)GO TO 15                                          DVISCP
      DO 10 N=NS1,NS2                                                  DVISCP
      AU(MS,N,3)=U(MSP1,N)-U(MS,N)                                     DVISCP
      AU(MS,N,4)=V(MSP1,N)-V(MS,N)                                     DVISCP
   10 AM(MS,N,2)=SH(MSP1,N)-SH(MS,N)                                   DVISCP
   15 CONTINUE                                                         DVISCP
      AM(1,1,3;NXM)=(YETA(1,1;NXM)*AM(1,1,1;NXM)-YXI(1,1;NXM)*AM(1,1,2; DVISCP
     1NXM))/AJ(1,1;NXM)                                                DVISCP
      AM(1,1,4;NXM)=(XXI(1,1;NXM)*AM(1,1,2;NXM)-XETA(1,1;NXM)*AM(1,1,1; DVISCP
     1NXM))/AJ(1,1;NXM)                                                DVISCP
      AN(1,1,1;NXM)=(YETA(1,1;NXM)*AU(1,1,1;NXM)-YXI(1,1;NXM)*AU(1,1,3; DVISCP
     1NXM))/AJ(1,1;NXM)                                                DVISCP
      AN(1,1,2;NXM)=(XXI(1,1;NXM)*AU(1,1,3;NXM)-XETA(1,1;NXM)*AU(1,1,1; DVISCP
     1NXM))/AJ(1,1;NXM)                                                DVISCP
      AN(1,1,3;NXM)=(YETA(1,1;NXM)*AU(1,1,2;NXM)-YXI(1,1;NXM)*AU(1,1,4; DVISCP
     1NXM))/AJ(1,1;NXM)                                                DVISCP
      AN(1,1,4;NXM)=(XXI(1,1;NXM)*AU(1,1,4;NXM)-XETA(1,1;NXM)*AU(1,1,2; DVISCP
     1NXM))/AJ(1,1;NXM)                                                DVISCP
      SIGX(1,1;NXM)=P(1,1;NXM)+2.*VIS(1,1;NXM)/3.*(AN(1,1,4;NXM)-2.*   DVISCP
     1AN(1,1,1;NXM))                                                   DVISCP
      SIGY(1,1;NXM)=P(1,1;NXM)+2.*VIS(1,1;NXM)/3.*(AN(1,1,1;NXM)-2.*   DVISCP
     1AN(1,1,4;NXM))                                                   DVISCP
      TAUXY(1,1;NXM)=-VIS(1,1;NXM)*(AN(1,1,2;NXM)+AN(1,1,3;NXM))       DVISCP
      QX(1,1;NXM)=-(VISL(1,1;NXM)/PR+VIST(1,1;NXM)/PRT)*AM(1,1,3;NXM)  DVISCP
      QY(1,1;NXM)=-(VISL(1,1;NXM)/PR+VIST(1,1;NXM)/PRT)*AM(1,1,4;NXM)  DVISCP
      IF(NSTRUT.EQ.0)RETURN                                            DVISCP
      DO 20 N=1,NS                                                     DVISCP
      NN=N-1+NS1                                                       DVISCP
      AUS(N,3)=US(N)-U(MS1,NN)                                         DVISCP
      AUS(N,4)=VS(N)-V(MS1,NN)                                         DVISCP
   20 AMS(N,2)=SHS(N)-SH(MS1,NN)                                       DVISCP
      DO 30 N=2,NS                                                     DVISCP
      AUS(N,1)=US(N)-US(N-1)                                           DVISCP
      AUS(N,2)=VS(N)-VS(N-1)                                           DVISCP
   30 AMS(N,1)=SHS(N)-SHS(N-1)                                         DVISCP
      AUS(1,1)=US(1)-U(MS,NS1M1)                                       DVISCP
      AUS(1,2)=VS(1)-V(MS,NS1M1)                                       DVISCP
      AMS(1,1)=SHS(1)-SH(MS,NS1M1)                                     DVISCP
      AMS(1,3;NS)=(YSETA(1;NS)*AMS(1,1;NS)-YSXI(1;NS)*AMS(1,2;NS))/    DVISCP
     1AJS(1;NS)                                                        DVISCP
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      AMS(1,4;NS)=(XSXI(1;NS)*AMS(1,2;NS)-XSETA(1;NS)*AMS(1,1;NS))/      DVISCP
     1AJS(1;NS)                                                          DVISCP
      ANS(1,1;NS)=(YSETA(1;NS)*AUS(1,1;NS)-YSXI(1;NS)*AUS(1,3;NS))/      DVISCP
     1AJS(1;NS)                                                          DVISCP
      ANS(1,2;NS)=(XSXI(1;NS)*AUS(1,3;NS)-XSETA(1;NS)*AUS(1,1;NS))/      DVISCP
     1AJS(1;NS)                                                          DVISCP
      ANS(1,3;NS)=(YSETA(1;NS)*AUS(1,2;NS)-YSXI(1;NS)*AUS(1,4;NS))/      DVISCP
     1AJS(1;NS)                                                          DVISCP
      ANS(1,4;NS)=(XSXI(1;NS)*AUS(1,4;NS)-XSETA(1;NS)*AUS(1,2;NS))/      DVISCP
     1AJS(1;NS)                                                          DVISCP
      SIGXS(1;NS)=PS(1;NS)+2.*VISS(1;NS)/3.*(ANS(1,4;NS)-2.*ANS(1,1;NS))DVISCP
      SIGYS(1;NS)=PS(1;NS)+2.*VISS(1;NS)/3.*(ANS(1,1;NS)-2.*ANS(1,4;NS))DVISCP
      TAUXYS(1;NS)=-VISS(1;NS)*(ANS(1,2;NS)+ANS(1,3;NS))                 DVISCP
      QXS(1;NS)= -VISS(1;NS)/PR*AMS(1,3;NS)                              DVISCP
      QYS(1;NS)= -VISS(1;NS)/PR*AMS(1,4;NS)                              DVISCP
      RETURN                                                             DVISCP
      END                                                                DVISCP
      SUBROUTINE DVISCC                                                  DVISCC
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1  DVISCC
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                               DVISCC
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3    DVISCC
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                       DVISCC
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),           DVISCC
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                         DVISCC
     2 PS(55),TS(55),SHS(55),HS(55)                                      DVISCC
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)              DVISCC
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),          DVISCC
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)          DVISCC
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)         DVISCC
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)                 DVISCC
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),                 DVISCC
     1 XETA(61,55),YETA(61,55),AJ(61,55)                                 DVISCC
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),               DVISCC
     1 YSETA(55),AJS(55)                                                 DVISCC
      COMMON/F9/INT(55),TE1(55),TE2(55),TE3(55),TE4(55)                  DVISCC
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF         DVISCC
      VIS(1,1;NXM)=VISL(1,1;NXM)+VIST(1,1;NXM)                           DVISCC
      NXMM=NXM-M1                                                        DVISCC
      AU(1,1,1;NXMM)=U(1,2;NXMM)-U(1,1;NXMM)                             DVISCC
      AU(1,N1,1;M1)=U(1,N1;M1)-U(1,N11;M1)                               DVISCC
      AU(1,1,2;NXMM)=V(1,2;NXMM)-V(1,1;NXMM)                             DVISCC
      AU(1,N1,2;M1)=V(1,N1;M1)-V(1,N11;M1)                               DVISCC
      AM(1,N1,1;M1)=SH(1,N1;M1)-SH(1,N11;M1)                             DVISCC
      AM(1,1,1;NXMM)=SH(1,2;NXMM)-SH(1,1;NXMM)                           DVISCC
      AU(1,1,3;NXM1)=J(2,1;NXM1)-U(1,1;NXM1)                             DVISCC
      TE1(1;N1)=Q8VGATHR(U(M11,1;NXM),INT(1;N1);TE1(1;N1))               DVISCC
      TE2(1;N1)=Q8VGATHR( U( M1,1;NXM),INT(1;N1);TE2(1;N1))              DVISCC
      TE3(1;N1)=TE2(1;N1)-TE1(1;N1)                                      DVISCC
      AU(M1,1,3;NXM)=Q8VSCATR(TE3(1;N1),INT(1;N1);AU(M1,1,3;NXM))        DVISCC
      AU(1,1,4;NXM1)=V(2,1;NXM1)-V(1,1;NXM1)                             DVISCC
      TE1(1;N1)=Q8VGATHR(V(M11,1;NXM),INT(1;N1);TE1(1;N1))               DVISCC
      TE2(1;N1)=Q8VGATHR( V( M1,1;NXM),INT(1;N1);TE2(1;N1))              DVISCC
      TE3(1;N1)=TE2(1;N1)-TE1(1;N1)                                      DVISCC
      AU(M1,1,4;NXM)=Q8VSCATR(TE3(1;N1),INT(1;N1);AU(M1,1,4;NXM))        DVISCC
      AM(1,1,2;NXM1)=SH(2,1;NXM1)-SH(1,1;NXM1)                           DVISCC
      TE1(1;N1)=Q8VGATHR(SH(M11,1;NXM),INT(1;N1);TE1(1;N1))              DVISCC
      TE2(1;N1)=Q8VGATHR(SH( M1,1;NXM),INT(1;N1);TE2(1;N1))              DVISCC
      TE3(1;N1)=TE2(1;N1)-TE1(1;N1)                                      DVISCC
      AM(M1,1,2;NXM)=Q8VSCATR(TE3(1;N1),INT(1;N1);AM(M1,1,2;NXM))        DVISCC
      IF(NSTRUT.EQ.0)GO TO 15                                            DVISCC
      DO 10 N=NS1,NS2                                                    DVISCC
      NN=N-NS1+1                                                         DVISCC
      AU(MS1,N,3)=US(NN)-U(MS1,N)                                        DVISCC
      AU(MS1,N,4)=VS(NN)-V(MS1,N)                                        DVISCC
10    AM(MS1,N,2)=SHS(NN)-SH(MS1,N)                                      DVISCC
15    CONTINUE                                                           DVISCC
      AM(1,1,3;NXM)=(YETA(1,1;NXM)*AM(1,1,1;NXM)-YXI(1,1;NXM)*AM(1,1,2; DVISCC
     1NXM))/AJ(1,1;NXM)                                                  DVISCC
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      AM(1,1,4;NXM)=(XXI(1,1;NXM)*AM(1,1,2;NXM)-XETA(1,1;NXM)*AM(1,1,1;  DVISCC
     1NXM))/AJ(1,1;NXM)                                                   DVISCC
      AN(1,1,1;NXM)=(YETA(1,1;NXM)*AU(1,1,1;NXM)-YXI(1,1;NXM)*AU(1,1,3;  DVISCC
     1NXM))/AJ(1,1;NXM)                                                   DVISCC
      AN(1,1,2;NXM)=(XXI(1,1;NXM)*AU(1,1,3;NXM)-XETA(1,1;NXM)*AU(1,1,1;  DVISCC
     1NXM))/AJ(1,1;NXM)                                                   DVISCC
      AN(1,1,3;NXM)=(YETA(1,1;NXM)*AU(1,1,2;NXM)-YXI(1,1;NXM)*AU(1,1,4;  DVISCC
     1NXM))/AJ(1,1;NXM)                                                   DVISCC
      AN(1,1,4;NXM)=(XXI(1,1;NXM)*AU(1,1,4;NXM)-XETA(1,1;NXM)*AU(1,1,2;  DVISCC
     1NXM))/AJ(1,1;NXM)                                                   DVISCC
      SIGX(1,1;NXM)=P(1,1;NXM)+2.*VIS(1,1;NXM)/3.*(AN(1,1,4;NXM)-2.*     DVISCC
     1AN(1,1,1;NXM))                                                      DVISCC
      SIGY(1,1;NXM)=P(1,1;NXM)+2.*VIS(1,1;NXM)/3.*(AN(1,1,1;NXM)-2.*     DVISCC
     1AN(1,1,4;NXM))                                                      DVISCC
      TAUXY(1,1;NXM)=-VIS(1,1;NXM)*(AN(1,1,2;NXM)+AN(1,1,3;NXM))         DVISCC
      QX(1,1;NXM)=-(VISL(1,1;NXM)/PR+VIST(1,1;NXM)/PRT)*AM(1,1,3;NXM)    DVISCC
      QY(1,1;NXM)=-(VISL(1,1;NXM)/PR+VIST(1,1;NXM)/PRT)*AM(1,1,4;NXM)    DVISCC
      IF(NSTRUT.EQ.0)RETURN                                               DVISCC
      DO 20 N=1,NS                                                        DVISCC
      NN=N-1+NS1                                                          DVISCC
      AUS(N,3)=US(N)-U(MS1,NN)                                            DVISCC
      AUS(N,4)=VS(N)-V(MS1,NN)                                            DVISCC
20    AMS(N,2)=SHS(N)-SH(MS1,NN)                                          DVISCC
      DO 30 N=1,NSM1                                                      DVISCC
      AUS(N,1)=US(N+1)-US(N)                                              DVISCC
      AUS(N,2)=VS(N+1)-VS(N)                                              DVISCC
30    AMS(N,1)=SHS(N+1)-SHS(N)                                            DVISCC
      AUS(NS,1)=U(MS,NS2P1)-US(NS)                                        DVISCC
      AUS(NS,2)=V(MS,NS2P1)-VS(NS)                                        DVISCC
      AMS(NS,1)=SH(MS,NS2P1)-SHS(NS)                                      DVISCC
      AMS(1,3;NS)=(YSETA(1;NS)*AMS(1,1;NS)-YSXI(1;NS)*AMS(1,2;NS))/      DVISCC
     1AJS(1;NS)                                                           DVISCC
      AMS(1,4;NS)=(XSXI(1;NS)*AMS(1,2;NS)-XSETA(1;NS)*AMS(1,1;NS))/      DVISCC
     1AJS(1;NS)                                                           DVISCC
      ANS(1,1;NS)=(YSETA(1;NS)*AUS(1,1;NS)-YSXI(1;NS)*AUS(1,3;NS))/      DVISCC
     1AJS(1;NS)                                                           DVISCC
      ANS(1,2;NS)=(XSXI(1;NS)*AUS(1,3;NS)-XSETA(1;NS)*AUS(1,1;NS))/      DVISCC
     1AJS(1;NS)                                                           DVISCC
      ANS(1,3;NS)=(YSETA(1;NS)*AUS(1,2;NS)-YSXI(1;NS)*AUS(1,4;NS))/      DVISCC
     1AJS(1;NS)                                                           DVISCC
      ANS(1,4;NS)=(XSXI(1;NS)*AUS(1,4;NS)-XSETA(1;NS)*AUS(1,2;NS))/      DVISCC
     1AJS(1;NS)                                                           DVISCC
      SIGXS(1;NS)=PS(1;NS)+2.*VISS(1;NS)/3.*(ANS(1,4;NS)-2.*ANS(1,1;NS))DVISCC
      SIGYS(1;NS)=PS(1;NS)+2.*VISS(1;NS)/3.*(ANS(1,1;NS)-2.*ANS(1,4;NS))DVISCC
      TAUXYS(1;NS)=-VISS(1;NS)*(ANS(1,2;NS)+ANS(1,3;NS))                  DVISCC
      QXS(1;NS)= -VISS(1;NS)/PR*AMS(1,3;NS)                               DVISCC
      QYS(1;NS)= -VISS(1;NS)/PR*AMS(1,4;NS)                               DVISCC
      RETURN                                                              DVISCC
      END                                                                 DVISCC
      SUBROUTINE VEC1                                                     VEC1
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1  VEC1
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                                VEC1
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),            VEC1
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                          VEC1
     2 PS(55),TS(55),SHS(55),HS(55)                                       VEC1
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),           VEC1
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)           VEC1
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)          VEC1
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)                  VEC1
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)                  VEC1
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),                  VEC1
     1 XETA(61,55),YETA(61,55),AJ(61,55)                                  VEC1
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),                VEC1
     1 YSETA(55),AJS(55)                                                  VEC1
      AN(1,1,4;NXM)=RO(1,1;NXM)*H(1,1;NXM)-P(1,1;NXM)                     VEC1
      AU(1,1,1;NXM)=RO(1,1;NXM)*U(1,1;NXM)                                VEC1
       AU(1,1,2;NXM)=AU(1,1,1;NXM)*U(1,1;NXM)+SIGX(1,1;NXM)               VEC1
       AU(1,1,3;NXM)=AU(1,1,1;NXM)*V(1,1;NXM)+TAUXY(1,1;NXM)              VEC1
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      AU(1,1,4;NXM)=(AN(1,1,4;NXM)+SIGX(1,1;NXM))*U(1,1;NXM)+V(1,1;NXM)VEC1
     1*TAUXY(1,1;NXM)+QX(1,1;NXM)                                      VEC1
      AN(1,1,1;NXM)=RO(1,1;NXM)*V(1,1;NXM)                             VEC1
      AN(1,1,2;NXM)=AN(1,1,1;NXM)*U(1,1;NXM)+TAUXY(1,1;NXM)            VEC1
      AN(1,1,3;NXM)=AN(1,1,1;NXM)*V(1,1;NXM)+SIGY(1,1;NXM)             VEC1
      AN(1,1,4;NXM)=(AN(1,1,4;NXM)+SIGY(1,1;NXM))*V(1,1;NXM)+U(1,1;NXM) VEC1
     1*TAUXY(1,1;NXM)+QY(1,1;NXM)                                      VEC1
      DO 20 I=1,4                                                      VEC1
      AM(1,1,I;NXM)=YETA(1,1;NXM)* AU(1,1,I;NXM)-XETA(1,1;NXM)*AN(1,1,I;VEC1
     1NXM)                                                             VEC1
      AN(1,1,I;NXM)=-YXI(1,1;NXM)* AU(1,1,I;NXM)+XXI(1,1;NXM)*AN(1,1,I; VEC1
     1NXM)                                                             VEC1
20    CONTINUE                                                         VEC1
      AU(1,1,1;NXM)=RO(1,1;NXM)*AJ(1,1;NXM)                            VEC1
      AU(1,1,2;NXM)=AU(1,1,1;NXM)*U(1,1;NXM)                           VEC1
      AU(1,1,3;NXM)=AJ(1,1,1;NXM)*V(1,1;NXM)                           VEC1
      AU(1,1,4;NXM)=(RO(1,1;NXM)*H(1,1;NXM)-P(1,1;NXM))*AJ(1,1;NXM)    VEC1
      IF(NSTRUT.EQ.0)RETURN                                            VEC1
      DO 30 N=1,NS                                                     VEC1
      ANS(N,4)=ROS(N)*HS(N)-PS(N)                                      VEC1
      AUS(N,1)=ROS(N)*US(N)                                            VEC1
      AUS(N,2)=AUS(N,1)*US(N)+SIGXS(N)                                 VEC1
      AUS(N,3)=AUS(N,1)*VS(N)+TAUXYS(N)                                VEC1
      AUS(N,4)=(ANS(N,4)+SIGXS(N))*US(N)+VS(N)*TAUXYS(N)+QXS(N)        VEC1
      ANS(N,1)=ROS(N)*VS(N)                                            VEC1
      ANS(N,2)=ANS(N,1)*US(N)+TAUXYS(N)                                VEC1
      ANS(N,3)=ANS(N,1)*VS(N)+SIGYS(N)                                 VEC1
      ANS(N,4)=(ANS(N,4)+SIGYS(N))*VS(N)+US(N)*TAUXYS(N)+QYS(N)        VEC1
30    CONTINUE                                                         VEC1
      DO 40 I=1,4                                                      VEC1
      DO 40 N=1,NS                                                     VEC1
      AMS(N,I)=YSETA(N)*AUS(N,I)-XSETA(N)*ANS(N,I)                     VEC1
      ANS(N,I)=-YSXI(N)*AUS(N,I)+XSXI(N)*ANS(N,I)                      VEC1
40    CONTINUE                                                         VEC1
      DO 50 N=1,NS                                                     VEC1
      AUS(N,1)=ROS(N)*AJS(N)                                           VEC1
      AUS(N,2)=AUS(N,1)*US(N)                                          VEC1
      AUS(N,3)=AUS(N,1)*VS(N)                                          VEC1
      AUS(N,4)=(POS(N)*HS(N)-PS(N))*AJS(N)                             VEC1
50    CONTINUE                                                         VEC1
      RETURN                                                           VEC1
      END                                                              VEC1
      SUBROUTINE IVEC1                                                 IVEC1
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 IVEC1
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                             IVEC1
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),         IVEC1
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                       IVEC1
     2 PS(55),TS(55),SHS(55),HS(55)                                    IVEC1
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)       IVEC1
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)               IVEC1
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),               IVEC1
     1 XETA(61,55),YETA(61,55),AJ(61,55)                               IVEC1
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),             IVEC1
     1 YSETA(55),AJS(55)                                               IVEC1
      AU(1,1,1;NXM)=RO(1,1;NXM)*U(1,1;NXM)                             IVEC1
       AU(1,1,2;NXM)=AU(1,1,1;NXM)*U(1,1;NXM)+P(1,1;NXM)               IVEC1
       AU(1,1,3;NXM)=AU(1,1,1;NXM)*V(1,1;NXM)                          IVEC1
       AU(1,1,4;NXM)=AU(1,1,1;NXM)*H(1,1;NXM)                          IVEC1
      AN(1,1,1;NXM)=RO(1,1;NXM)*V(1,1;NXM)                             IVEC1
      AN(1,1,2;NXM)=AN(1,1,1;NXM)*U(1,1;NXM)                           IVEC1
      AN(1,1,3;NXM)=AN(1,1,1;NXM)*V(1,1;NXM)+P(1,1;NXM)                IVEC1
      AN(1,1,4;NXM)=AN(1,1,1;NXM)*H(1,1;NXM)                           IVEC1
      DO 20 I=1,4                                                      IVEC1
      AM(1,1,I;NXM)=YETA(1,1;NXM)* AU(1,1,I;NXM)-XETA(1,1;NXM)*AN(1,1,I;IVEC1
     1NXM)                                                             IVEC1
      AN(1,1,I;NXM)=-YXI(1,1;NXM)* AU(1,1,I;NXM)+XXI(1,1;NXM)*AN(1,1,I; IVEC1
     1NXM)                                                             IVEC1
20    CONTINUE                                                         IVEC1
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      AU(1,1,1;NXM)=RO(1,1;NXM)*AJ(1,1;NXM)
      AU(1,1,2;NXM)=AU(1,1,1;NXM)*U(1,1;NXM)
      AU(1,1,3;NXM)=AU(1,1,1;NXM)*V(1,1;NXM)
      AU(1,1,4;NXM)=(RO(1,1;NXM)*H(1,1;NXM)-P(1,1;NXM))*AJ(1,1;NXM)
      IF(NSTRUT.EQ.0)RETURN
      DO 30 N=1,NS
      AUS(N,1)=ROS(N)*US(N)
      AUS(N,2)=AUS(N,1)*US(N)+PS(N)
      AUS(N,3)=AUS(N,1)*VS(N)
      AUS(N,4)=AUS(N,1)*HS(N)
      ANS(N,1)=ROS(N)*VS(N)
      ANS(N,2)=ANS(N,1)*US(N)
      ANS(N,3)=ANS(N,1)*VS(N)+PS(N)
      ANS(N,4)=ANS(N,1)*HS(N)
   30 CONTINUE
      DO 40 I=1,4
      DO 40 N=1,NS
      AMS(N,I)=YSETA(N)*AUS(N,I)-XSETA(N)*ANS(N,I)
      ANS(N,I)=-YSXI(N)*AUS(N,I)+XSXI(N)*ANS(N,I)
   40 CONTINUE
      DO 50 N=1,NS
      AUS(N,1)=ROS(N)*AJS(N)
      AUS(N,2)=AUS(N,1)*US(N)
      AUS(N,3)=AUS(N,1)*VS(N)
      AUS(N,4)=(ROS(N)*HS(N)-PS(N))*AJS(N)
   50 CONTINUE
      RETURN
      END
      SUBROUTINE DAMPP
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),
     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F10/DT(61,55),DTM
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
      QX(1,1;NXM)=GAMA*RGAS*T(1,1;NXM)
      QX(1,1;NXM)=VSQRT(QX(1,1;NXM);QX(1,1;NXM))
      SIGX(1,1;NXM)=(VABS(U(1,1;NXM);SIGY(1,1;NXM))+QX(1,1;NXM))
      SIGY(2,2;NXM4)=P(2,3;NXM4)-2.*P(2,2;NXM4)+P(2,1;NXM4)
      SIGY(2,2;NXM4)=VABS(SIGY(2,2;NXM4);SIGY(2,2;NXM4))
        QY(2,2;NXM4)=T(2,3;NXM4)-2.*T(2,2;NXM4)+T(2,1;NXM4)
      QY(2,2;NXM4)=VABS(QY(2,2;NXM4);QY(2,2;NXM4))
      SIGX(2,2;NXM4)=SIGX(2,2;NXM4)*(SIGY(2,2;NXM4)*CCP/
     1(P(2,3;NXM4)+2.*P(2,2;NXM4)+P(2,1;NXM4))+QY(2,2;NXM4)*CCT/
     1(T(2,3;NXM4)+2.*T(2,2;NXM4)+T(2,1;NXM4)))
      QX(1,1;NXM)=(VABS(V(1,1;NXM);SIGY(1,1;NXM))+QX(1,1;NXM))
      SIGY(2,2;NXM4)=P(3,2;NXM4)-2.*P(2,2;NXM4)+P(1,2;NXM4)
      SIGY(2,2;NXM4)=VABS(SIGY(2,2;NXM4);SIGY(2,2;NXM4))
        QY(2,2;NXM4)=T(3,2;NXM4)-2.*T(2,2;NXM4)+T(1,2;NXM4)
      QY(2,2;NXM4)=VABS(QY(2,2;NXM4);QY(2,2;NXM4))
      SIGY(2,2;NXM4)=             QX(2,2;NXM4)*(SIGY(2,2;NXM4)*CCP/
     1(P(3,2;NXM4)+2.*P(2,2;NXM4)+P(1,2;NXM4))+QY(2,2;NXM4)*CCT/(
     2 T(3,2;NXM4)+2.*T(2,2;NXM4)+T(1,2;NXM4)))
      IF(NSTRUT.EQ.0)GO TO 35
      DO 30 N=NS1,NS2
      NN=N-NS1+1
      SIGY(MS1,N)=QX(MS1,N)*(ABS(PS(NN)-2.*P(MS1,N)+P(MS2,N))*CCP/(PS(NN
     1)+2.*P(MS1,N)+P(MS2,N))+ABS(TS(NN)-2.*T(MS1,N)+T(MS2,N))*CCT/(TS(
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     2NN)+2.*T(MS1,N)+T(MS2,N)))
30    CONTINUE
35    CONTINUE
      DO 100 I=1,4
      QX(2,2;NXM4)=SIGX(2,2;NXM4)*(AU(2,2,I;NXM4)-AU(2,1,I;NXM4))
      QY(2,2;NXM4)=SIGY(2,2;NXM4)*(AU(2,2,I;NXM4)-AU(1,2,I;NXM4))
      DO 10 N=2,N11
      QX(1,N)=0.
      QX(M1,N)=0.
      QY(1,N)=0.
10    QY(M1,N)=0.
      IF(NSTRUT.EQ.0)GO TO 25
      DO 20 N=NS1,NS2
      QX(MS,N)=0.
20    QY(MS,N)=0.
25    CONTINUE
      AM(2,2,I;NXM4)=AM(2,2,I;NXM4)-QX(2,2;NXM4)/XXI(2,2;NXM4)
      AN(2,2,I;NXM4)=AN(2,2,I;NXM4)-QY(2,2;NXM4)/YETA(2,2;NXM4)
100   CONTINUE
      RETURN
      END
      SUBROUTINE DAMPC
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),
     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F10/DT(61,55),DTM
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
      QX(1,1;NXM)=GAMA*RGAS*T(1,1;NXM)
      QX(1,1;NXM)=VSQRT(QX(1,1;NXM);QX(1,1;NXM))
      SIGX(1,1;NXM)=(VABS(U(1,1;NXM);SIGY(1,1;NXM))+QX(1,1;NXM))
      SIGY(2,2;NXM4)=P(2,3;NXM4)-2.*P(2,2;NXM4)+P(2,1;NXM4)
      SIGY(2,2;NXM4)=VABS(SIGY(2,2;NXM4);SIGY(2,2;NXM4))
        QY(2,2;NXM4)=T(2,3;NXM4)-2.*T(2,2;NXM4)+T(2,1;NXM4)
      QY(2,2;NXM4)=VABS(QY(2,2;NXM4);QY(2,2;NXM4))
      SIGX(2,2;NXM4)=SIGX(2,2;NXM4)*(SIGY(2,2;NXM4)*CCP/
     1(P(2,3;NXM4)+2.*P(2,2;NXM4)+P(2,1;NXM4))+QY(2,2;NXM4)*CCT/
     1(T(2,3;NXM4)+2.*T(2,2;NXM4)+T(2,1;NXM4)))
      QX(1,1;NXM)=(VABS(V(1,1;NXM);SIGY(1,1;NXM))+QX(1,1;NXM))
      SIGY(2,2;NXM4)=P(3,2;NXM4)-2.*P(2,2;NXM4)+P(1,2;NXM4)
      SIGY(2,2;NXM4)=VABS(SIGY(2,2;NXM4);SIGY(2,2;NXM4))
        QY(2,2;NXM4)=T(3,2;NXM4)-2.*T(2,2;NXM4)+T(1,2;NXM4)
      QY(2,2;NXM4)=VABS(QY(2,2;NXM4);QY(2,2;NXM4))
      SIGY(2,2;NXM4)=              QX(2,2;NXM4)*(SIGY(2,2;NXM4)*CCP/
     1(P(3,2;NXM4)+2.*P(2,2;NXM4)+P(1,2;NXM4))+QY(2,2;NXM4)*CCT/(
     2 T(3,2;NXM4)+2.*T(2,2;NXM4)+T(1,2;NXM4)))
      IF(NSTRUT.EQ.0)GO TO 35
      DO 30 N=NS1,NS2
      NN=N-NS1+1
      SIGY(MS1,N)=QX(MS1,N)*(ABS(PS(NN)-2.*P(MS1,N)+P(MS2,N))*CCP/(PS(NN
     1)+2.*P(MS1,N)+P(MS2,N))+ABS(TS(NN)-2.*T(MS1,N)+T(MS2,N))*CCT/(TS(
     2NN)+2.*T(MS1,N)+T(MS2,N)))
30    CONTINUE
35    CONTINUE
      DO 100 I=1,4
      QX(2,2;NXM4)=SIGX(2,2;NXM4)*(AU(2,3,I;NXM4)-AU(2,2,I;NXM4))
      QY(2,2;NXM4)=SIGY(2,2;NXM4)*(AU(3,2,I;NXM4)-AU(2,2,I;NXM4))
```

```
      DO 10 N=2,N11
      QX(1,N)=0.
      QX(M1,N)=0.
      QY(1,N)=0.
10    QY(M1,N)=0.
      IF(NSTRUT.EQ.0)GO TO 25
      DO 20 N=NS1,NS2
      NN=N-NS1+1
      QY(MS1,N)=SIGY(MS1,N)*(AUS(NN,I)-AU(MS1,N,I))
      QX(MS,N)=0.
20    QY(MS,N)=0.
25    CONTINUE
      AM(2,2,I;NXM4)=AM(2,2,I;NXM4)-QX(2,2;NXM4)/XXI(2,2;NXM4)
      AN(2,2,I;NXM4)=AN(2,2,I;NXM4)-QY(2,2;NXM4)/YETA(2,2;NXM4)
100   CONTINUE
      RETURN
      END
      SUBROUTINE VEC2
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),
     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
      COMMON/F14/DAU(61,55,4),BDAU(55,4),BDAUS(55,4),TI(55,5),
     1CCIMPY,GM1,GM2,GM3,GM4,GM5
      RO(2,2;NXM4)=AU1(2,2,1;NXM4)/AJ(2,2;NXM4)
       U(2,2;NXM4)=AU1(2,2,2;NXM4)/AU1(2,2,1;NXM4)
       V(2,2;NXM4)=AU1(2,2,3;NXM4)/AU1(2,2,1;NXM4)
      QX(2,2;NXM4)=(U(2,2;NXM4)*U(2,2;NXM4)+V(2,2;NXM4)*V(2,2;NXM4))/2.
      SH(2,2;NXM4)=(AU1(2,2,4;NXM4)/AU1(2,2,1;NXM4)-QX(2,2;NXM4))*GAMA
      H(2,2;NXM4)=SH(2,2;NXM4)+QX(2,2;NXM4)
      P(2,2;NXM4)=GM2*RO(2,2;NXM4)*SH(2,2;NXM4)
      T(2,2;NXM4)=SH(2,2;NXM4)/CP
      RETURN
      END
      SUBROUTINE BOUND
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),
     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),
     1 YSETA(55),AJS(55)
      COMMON/F9/INT(55),TE1(55),TE2(55),TE3(55),TE4(55)
      COMMON/F10/DT(61,55),DTM
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
      TE1(2;N12)=Q8VGATHR(T(M11,2;NXM3),INT(1;N12);TE1(2;N12))
      TE2(2;N12)=Q8VGATHR(P(M11,2;NXM3),INT(1;N12);TE2(2;N12))
      TE3(2;N12)=TE2(2;N12)/RGAS/TE1(2;N12)
      TE4(2;N12)=CP*TE1(2;N12)
       T(M1,2;NXM3)=Q8VSCATR(TE1(2;N12),INT(1;N12); T(M1,2;NXM3))
      P(M1,2;NXM3)=Q8VSCATR(TE2(2,N12),INT(1;N12);P(M1,2;NXM3))
      RO(M1,2;NXM3)=Q8VSCATR(TE3(2;N12),INT(1;N12);RO(M1,2;NXM3))
      SH(M1,2;NXM3)=Q8VSCATR(TE4(2;N12),INT(1;N12);SH(M1,2;NXM3))
      TE1(2;N12)=0.
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      TE2(2;N12)=0.
      U(M1,2;NXM3)=Q8VSCATR(TE1(2;N12),INT(1;N12);U(M1,2;NXM3))
      V(M1,2;NXM3)=Q8VSCATR(TE2(2;N12),INT(1;N12);V(M1,2;NXM3))
      TE3(2;N12)=TE4(2;N12)+(TE1(2;N12)*TE1(2;N12)+TE2(2;N12)*TE2(2;N12)
     1)/2.
      H(M1,2;NXM3)=Q8VSCATR(TE3(2;N12),INT(1;N12);H(M1,2;NXM3))
      IF(NSTRUT.EQ.0)GO TO 15
      DO 10 N=NS1,NS2
      U(MS,N)=0.
      V(MS,N)=0.
      P(MS,N)=P(MSP1,N)
      T(MS,N)=T(MSP1,N)
      SH(MS,N)=CP*T(MS,N)
      RO(MS,N)=P(MS,N)/RGAS/T(MS,N)
   10 H(MS,N)=SH(MSP1,N)
      DO 20 N=1,NS
      NN=N+NS1M1
      US(N)=0.
      VS(N)=0.
      PS(N)=P(MS1,NN)
      TS(N)=T(MS1,NN)
      SHS(N)=CP*TS(N)
      ROS(N)=PS(N)/RGAS/TS(N)
   20 HS(N)=SHS(N)
   15 CONTINUE
      DO 25 N=2,N11
      T(1,N)=T(2,N)
      P(1,N)=P(2,N)
      SH(1,N)=CP*T(1,N)
      RO(1,N)=RO(2,N)
      U(1,N)=U(2,N)
      V(1,N)=V(2,N)
   25 H(1,N)=H(2,N)
      IF(LSYM.EQ.0)GO TO 55
      DO 60 N=2,N11
      V(1,N)=0.
   60 H(1,N)=SH(1,N)+U(1,N)*U(1,N)/2.
   55 CONTINUE
C     COWL PLATE OR CENTER STRUT STARTS FROM N=NCWL1 AND ENDS AT NCWL2.
      IF(NCWL.EQ.0)GO TO 35
      DO 30 N=NCWL1,NCWL2
      H(1,N)=SH(1,N)
      U(1,N)=0.
   30 V(1,N)=0.
   35 CONTINUE
      IF(LEXIT.EQ.0)GO TO 36
      U(1,N1;M1)=2.*U(1,N11;M1)-U(1,N12;M1)
      V(1,N1;M1)=2.*V(1,N11;M1)-V(1,N12;M1)
       P(1,N1;M1)=2.* P(1,N11;M1)- P(1,N12;M1)
      SH(1,N1;M1)=2.*SH(1,N11;M1)-SH(1,N12;M1)
      GO TO 37
   36 CONTINUE
      U(1,N1;M1)=U(1,N11;M1)
      V(1,N1;M1)=V(1,N11;M1)
      P(1,N1;M1)=P(1,N11;M1)
      SH(1,N1;M1)=SH(1,N11;M1)
   37 CONTINUE
      T(1,N1;M1)=SH(1,N1;M1)/CP
      RO(1,N1;M1)=P(1,N1;M1)/(RGAS*T(1,N1;M1))
      H(1,N1;M1)=SH(1,N1;M1)+(U(1,N1;M1)*U(1,N1;M1)+V(1,N1;M1)*
     1V(1,N1;M1))/2.
      II=Q8SLT(T(1,1;NXM),0.5)
      IF(II.EQ.NXM)GO TO 50
      WRITE(6,500)L
  500 FORMAT(/,2X,'NEGATIVE TEMPERATURE IN THE FIELD',15X,
     1       'NO. OF ITERATIONS=',I5)
      DO 40 N=1,N1
      WRITE(6,550)N,X(1,N)
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      DO 40 MM=1,M1
      M=M1-MM+1
      WRITE(6,560)Y(M,N),U(M,N),V(M,N),P(M,N),T(M,N),H(M,N),VIST(M,N)
 40   CONTINUE
      IF(NSTRUT.EQ.0)GO TO 45
      WRITE(6,570)
      WRITE(6,560)(YS(N),US(N),VS(N),PS(N),TS(N),HS(N),VISS(N),N=1,NS)
 45   CONTINUE
      LK=2
      RETURN
 50   CONTINUE
 550  FORMAT(/,8X,'Y',10X,'U',10X,'V',11X,'P',11X,'T',12X,' H',10X,
     1'VIST',10X,'BODY STATION=',I3,5X,'X=',F10.5)
 560  FORMAT(2X,F12.5,F12.5,F12.5,F13.4,F12.5,2F15.5)
 570  FORMAT(/,8X,'YS',9X,'US',9X,'VS',10X,'PS',10X,'TS',12X,'HS',
     110X,'VISS',/)
      VISL(1,1;NXM)=VSQRT(T(1,1;NXM);VISL(1,1;NXM))
      VISL(1,1;NXM)=CVIS*VISL(1,1;NXM)*T(1,1;NXM)/(T(1,1;NXM)+110.)
      IF(NSTRUT.EQ.0)RETURN
      VISS(1;NS)=VSQRT(TS(1;NS);VISS(1;NS))
      VISS(1;NS)=CVIS*VISS(1;NS)*TS(1;NS)/(TS(1;NS)+110.)
      RETURN
      END
      SUBROUTINE IBOUND
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),
     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),
     1 YSETA(55),AJS(55)
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
      DO 5 N=2,N11
      RO(1,N)=RO(2,N)
       P(1,N)= P(2,N)
       T(1,N)= T(2,N)
       H(1,N)= H(2,N)
      SH(1,N)=SH(2,N)
      CON1=YXI(1,N)/XXI(1,N)
      CON2=1.+CON1*CON1
      U(1,N)=(H(1,N)-SH(1,N))*2./CON2
      U(1,N)=SQRT(U(1,N))
  5   V(1,N)=CON1*U(1,N)
      DO 20 N=2,N11
      RO(M1,N)=RO(M11,N)
      SH(M1,N)=SH(M11,N)
       P(M1,N)= P(M11,N)
       T(M1,N)= T(M11,N)
       H(M1,N)= H(M11,N)
      CON1=YXI(M1,N)/XXI(M1,N)
      CON2=1.+CON1*CON1
      U(M1,N)=(H(M1,N)-SH(M1,N))*2./CON2
      U(M1,N)=SQRT(U(M1,N))
 20   V(M1,N)=CON1*U(M1,N)
      IF(LSYM.EQ.1)GO TO 60
      IF(NCWL.EQ.0)GO TO 62
      IF(NCWL1.LE.2.AND.NCWL2.GE.N11)GO TO 60
      DO 50 N=1,NCWLM
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      U(1,N)=U(2,N)
 50   V(1,N)=V(2,N)
      IF(NCWL2.GE.N11)GO TO 60
      DO 55 N=NCWLP,N11
      U(1,N)=U(2,N)
 55   V(1,N)=V(2,N)
      GO TO 60
 62   CONTINUE
      DO 56 N=2,N11
      U(1,N)=U(2,N)
  56  V(1,N)=V(2,N)
 60   CONTINUE
      IF(NSTRUT.EQ.0)GO TO 6
      DO 10 N=1,NS
      NN=N+NS1-1
      RO(MS,NN)=RO(MSP1,NN)
      SH(MS,NN)=SH(MSP1,NN)
       P(MS,NN)= P(MSP1,NN)
       T(MS,NN)= T(MSP1,NN)
       H(MS,NN)= H(MSP1,NN)
      CON1=YXI(MS,NN)/XXI(MS,NN)
      CON2=1.+CON1*CON1
      U(MS,NN)=(H(MS,NN)-SH(MS,NN))*2./CON2
      U(MS,NN)=SQRT(U(MS,NN))
      V(MS,NN)=CON1*U(MS,NN)
      ROS(N)=RO(MS1,NN)
       PS(N)= P(MS1,NN)
       TS(N)= T(MS1,NN)
       HS(N)= H(MS1,NN)
      SHS(N)=SH(MS1,NN)
      CON1=YSXI(N)/XSXI(N)
      CON2=1.+CON1*CON1
      US(N)=(HS(N)-SHS(N))*2./CON2
      US(N)=SQRT(US(N))
  10  VS(N)=CON1*US(N)
 6    CONTINUE
      IF(LEXIT.EQ.0) GO TO 36
      U(1,N1;M1)=2.*U(1,N11;M1)-U(1,N12;M1)
      V(1,N1;M1)=2.*V(1,N11;M1)-V(1,N12;M1)
      SH(1,N1;M1)=2.*SH(1,N11;M1)-SH(1,N12;M1)
       P(1,N1;M1)=2.* P(1,N11;M1)- P(1,N12;M1)
      GO TO 37
  36  CONTINUE
      U(1,N1;M1)=U(1,N11;M1)
      V(1,N1;M1)=V(1,N11;M1)
      SH(1,N1;M1)=SH(1,N11;M1)
      P(1,N1;M1)=P(1,N11;M1)
  37  CONTINUE
      T(1,N1;M1)=SH(1,N1;M1)/CP
      RO(1,N1;M1)=P(1,N1;M1)/(RGAS*T(1,N1;M1))
      H(1,N1;M1)=SH(1,N1;M1)+(U(1,N1;M1)*U(1,N1;M1)+V(1,N1;M1)*
     1V(1,N1;M1))/2.
      II=Q8SLT(T(1,1;NXM),0.5)
      IF(II.EQ.NXM)RETURN
      WRITE(6,500)L
 500  FORMAT(/,2X,'NEGATIVE TEMPERATURE IN THE FIELD',15X,
     1           'NO. OF ITERATIONS =',I5)
      DO 40 N=1,N1
      WRITE(6,550)N,X(1,N)
      DO 40 MM=1,M1
      M=M1-MM+1
      WRITE(6,560)Y(M,N),U(M,N),V(M,N),P(M,N),T(M,N),H(M,N)
 40   CONTINUE
      IF(NSTRUT.EQ.0)GO TO 45
      WRITE(6,570)
      WRITE(6,560)(YS(N),US(N),VS(N),PS(N),TS(N),HS(N),N=1,NS)
 45   CONTINUE
 550  FORMAT(/,8X,'Y',10X,'U',10X,'V',11X,'P',11X,'T',12X,' H',10X,
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     1'BODY STATION=',I3,5X,'X=',F10.5)                                 IBOUND
 560  FORMAT(2X,F12.5,F12.5,F12.5,F13.4,F12.5,F15.5)                    IBOUND
 570  FORMAT(/,8X,'YS',9X,'US',9X,'VS',10X,'PS',10X,'TS',12X,'HS',/)     IBOUND
      LK=2                                                              IBOUND
      RETURN                                                            IBOUND
      END                                                               IBOUND
      SUBROUTINE VORT                                                   VORT
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 VORT
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                              VORT
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3   VORT
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                      VORT
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),          VORT
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                        VORT
     2 PS(55),TS(55),SHS(55),HS(55)                                     VORT
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),         VORT
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)         VORT
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),                VORT
     1 XETA(61,55),YETA(61,55),AJ(61,55)                                VORT
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),              VORT
     1 YSETA(55),AJS(55)                                                VORT
      SIGX(2,1;NXM2)=(U(3,1;NXM2)-U(1,1;NXM2))/2.                       VORT
      SIGY(2,1;NXM2)=(V(3,1;NXM2)-V(1,1;NXM2))/2.                       VORT
      DO 10 N=1,N1                                                      VORT
      SIGX(1,N)=U(2,N)-U(1,N)                                           VORT
      SIGY(1,N)=V(2,N)-V(1,N)                                           VORT
      SIGY(1,N)=V(2,N)-V(1,N)                                           VORT
      SIGX(M1,N)=U(M1,N)-U(M11,N)                                       VORT
 10   SIGY(M1,N)=V(M1,N)-V(M11,N)                                       VORT
      QX(1,2;NXM3)=(U(1,3;NXM3)-U(1,1;NXM3))/2.                         VORT
      QY(1,2;NXM3)=(V(1,3;NXM3)-V(1,1;NXM3))/2.                         VORT
      DO 20 M=1,M1                                                      VORT
      QX(M,1)=U(M,2)-U(M,1)                                             VORT
      QY(M,1)=V(M,2)-V(M,1)                                             VORT
      QX(M,N1)=U(M,N1)-U(M,N11)                                         VORT
 20   QY(M,N1)=V(M,N1)-V(M,N11)                                         VORT
      IF(NSTRUT.EQ.0)GO TO 50                                           VORT
      DO 30 N=NS1,NS2                                                   VORT
      NN=N-NS1+1                                                        VORT
      SIGX(MS,N)=U(MSP1,N)-U(MS,N)                                      VORT
      SIGY(MS,N)=V(MSP1,N)-V(MS,N)                                      VORT
      SIGX(MS1,N)=(US(NN)-U(MS2,N))/2.                                  VORT
 30   SIGY(MS1,N)=(VS(NN)-V(MS2,N))/2.                                  VORT
      DO 40 N=2,NSM1                                                    VORT
 40     QXS(N)=(US(N+1)-US(N-1))/2.                                     VORT
        QXS(1)=(US(2)-U(MS,NS1M1))/2.                                   VORT
      QXS(NS)=(U(MS,NS2P1)-US(NSM1))/2.                                 VORT
      DO 60 N=1,NS                                                      VORT
      NN=N-1+NS1                                                        VORT
 60   SIGXS(N)=US(N)-U(MS1,NN)                                          VORT
      QXS(1;NS)=(XSXI(1;NS)*SIGXS(1;NS)-XSETA(1;NS)*  QXS(1;NS))/AJS(1; VORT
     1NS)                                                               VORT
 50   CONTINUE                                                          VORT
      QX(1,1;NXM)=(XXI(1,1;NXM)*SIGX(1,1;NXM)-XETA(1,1;NXM)*  QX(1,1;   VORT
     1NXM))/AJ(1,1;NXM)                                                 VORT
      QY(1,1;NXM)=(YETA(1,1;NXM)*  QY(1,1;NXM)-YXI(1,1;NXM)*SIGY(1,1;   VORT
     1NXM))/AJ(1,1;NXM)                                                 VORT
      TAUXY(1,1;NXM)=QX(1,1;NXM)-QY(1,1;NXM)                            VORT
      TAUXY(1,1;NXM)=VABS(TAUXY(1,1;NXM);TAUXY(1,1;NXM))                VORT
      RETURN                                                            VORT
      END                                                               VORT
      SUBROUTINE EDDY(NNX1,NNX2,NY1,NY2,NWALL,NSTR)                     EDDY
C     EDDY VISCOSITY MODEL TAKEN FROM AIAA PAPER NO. 78-257 BY BALDWIN   EDDY
C     AND LOMAX.  NWALL = 1 FOR ONE WALL AND = 2 FOR TWO WALLS.          EDDY
      DIMENSION YD(61),VISTI(61),VISTO(61),FY(61),UDIF1(61)             EDDY
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 EDDY
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                              EDDY
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),          EDDY
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                        EDDY
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     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),
     1 YSETA(55),AJS(55)
      REAL K,KK
      DATA AP,CCP,CKLEB,CWK,K,KK/26.,1.6,0.3,0.25,0.4,.0168/
C     NSTR EQUAL TO 1  FOR THE REGION WHERE LOWER SURFACE OF THE STRUT
C     FORMS THE UPPER WALL OF THE DOMAIN IN WHICH EDDY VISCOSITY IS
C     BEING CALCULATED.   IT IS ZERO OTHERWISE.
      NNY=NY2-NY1+1
      NNY1=NY1
      NNY2=NY2
      IF(NWALL.EQ.1)GO TO 5
      NNY2=NY2
      NNY1=NY1+NNY/2
 5    CONTINUE
      NNY2M1=NNY2-1
      NNY1P1=NNY1+1
      NNY=NNY2-NNY1+1
      DO 100 N=NNX1,NNX2
      IF(NSTR.EQ.1)GO TO 10
      TAUW=ABS(VIS(NNY2,N)*QX(NNY2,N))*RO(NNY2,N)
      YPI=SQRT(TAUW)/VIS(NNY2,N)
      DO 20 M=NNY1,NNY2
 20   YD(M)=Y(NNY2,N)-Y(M,N)
      GO TO 15
 10   NN=N-NS1+1
      TAUW=ABS(VISS(NN)*QXS(NN))*ROS(NN)
      YPI=SQRT(TAUW)/VISS(NN)
      DO 30 M=NNY1,NNY2
 30   YD(M)=YS(NN)-Y(M,N)
 15   CONTINUE
      DO 40 M=NNY1,NNY2
      YP=YPI*YD(M)
      RL=-YP/AP
      RL=EXP(RL)
      RL=YD(M)*(1.-RL)
      VISTI(M)=RO(M,N)*K*K*RL*RL*TAUXY(M,N)
      UDIF1(M)=U(M,N)*U(M,N)+V(M,N)*V(M,N)
      UDIF1(M)=SQRT(UDIF1(M))
 40   FY(M)=RL*TAUXY(M,N)
C
C     SOMETIMES CALCULATIONS OF FYMAX MAY REQUIRE SOME ATTENTION DUE
C     TO MORE THAN ONE MAXIMA OCCURING IN FUNCTION FY.
C
      FYMAX=FY(NNY2M1)
       YMAX=YD(NNY2M1)
      DO 50 MM=NNY1P1,NNY2M1
      M=NNY2-MM+NNY1
      IF(FY(M-1).GT.FY(M))GO TO 50
      FYMAX=FY(M)
      YMAX=YD(M)
      GO TO 51
 50   CONTINUE
      FYMAX=FY(NNY1P1)
       YMAX=YD(NNY1P1)
 51   CONTINUE
      UDIF=Q8SMAX(UDIF1(NNY1;NNY))
      FWAKE1=YMAX*FYMAX
      FWAKE2=CWK*YMAX*UDIF*UDIF/FYMAX
      FWAKE=AMIN1(FWAKE1,FWAKE2)
      DO 60 M=NNY1,NNY2
      FKLEB=1./(1.+5.5*(CKLEB*YD(M)/YMAX)**6)
 60   VISTO(M)=KK*CCP*RO(M,N)*FWAKE*FKLEB
```

```
      IOUT=0                                                            EDDY
      DO 70 MM=NNY1,NNY2                                                EDDY
      M=NNY2-MM+NNY1                                                    EDDY
      DVIST=VISTO(M)-VISTI(M)                                           EDDY
      IF(DVIST.LE.0.)IOUT=1                                             EDDY
      VIST(M,N)=VISTI(M)                                                EDDY
      IF(IOUT.EQ.1)VIST(M,N)=VISTO(M)                                   EDDY
   70 CONTINUE                                                          EDDY
  100  CONTINUE                                                         EDDY
      IF(NWALL.EQ.1)GO TO 500                                           EDDY
      NNY2=NNY1-1                                                       EDDY
      NNY1=NY1                                                          EDDY
      NNY=NNY2-NNY1+1                                                   EDDY
      NNY1P1=NNY1+1                                                     EDDY
      NNY1P2=NNY1+2                                                     EDDY
      DO 200 N=NNX1,NNX2                                                EDDY
      TAUW=ABS(VIS(NNY1,N)*QX(NNY1,N))*RO(NNY1,N)                       EDDY
      YPI=SQRT(TAUW)/VIS(NNY1,N)                                        EDDY
      DO 210 M=NNY1,NNY2                                                EDDY
      YD(M)=Y(M,N)-Y(NNY1,N)                                            EDDY
      YP=YPI*YD(M)                                                      EDDY
      RL=-YP/AP                                                         EDDY
      RL=EXP(RL)                                                        EDDY
      RL=YD(M)*(1.-RL)                                                  EDDY
      VISTI(M)=RO(M,N)*K*K*RL*RL*TAUXY(M,N)                             EDDY
      UDIF1(M)=U(M,N)*U(M,N)+V(M,N)*V(M,N)                              EDDY
      UDIF1(M)=SQRT(UDIF1(M))                                           EDDY
  210 FY(M)=RL*TAUXY(M,N)                                               EDDY
C                                                                       EDDY
C     SOMETIMES CALCULATIONS OF FYMAX MAY REQUIRE SOME ATTENTION DUE    EDDY
C     TO MORE THAN ONE MAXIMA OCCURING IN FUNCTION FY.                  EDDY
C                                                                       EDDY
      FYMAX=FY(NNY1P1)                                                  EDDY
       YMAX=YD(NNY1P1)                                                  EDDY
      DO 220 M=NNY1P2,NNY2                                              EDDY
      IF(FY(M).GT.FY(M-1))GO TO 220                                     EDDY
      FYMAX=FY(M-1)                                                     EDDY
      YMAX=YD(M-1)                                                      EDDY
      GO TO 221                                                         EDDY
  220 CONTINUE                                                          EDDY
      FYMAX=FY(NNY2)                                                    EDDY
       YMAX=YD(NNY2)                                                    EDDY
  221 CONTINUE                                                          EDDY
      UDIF=Q8SMAX(UDIF1(NNY1;NNY))                                      EDDY
      FWAKE1=YMAX*FYMAX                                                 EDDY
      FWAKE2=CWK*YMAX*UDIF*UDIF/FYMAX                                   EDDY
      FWAKE=AMIN1(FWAKE1,FWAKE2)                                        EDDY
      DO 230 M=NNY1,NNY2                                                EDDY
      FKLEB=1./(1.+5.5*(CKLEB*YD(M)/YMAX)**6)                           EDDY
  230 VISTO(M)=KK*CCP*RO(M,N)*FWAKE*FKLEB                               EDDY
      IOUT=0                                                            EDDY
      DO 240 M=NNY1,NNY2                                                EDDY
      DVIST=VISTO(M)-VISTI(M)                                           EDDY
      IF(DVIST.LE.0.)IOUT=1                                             EDDY
      VIST(M,N)=VISTI(M)                                                EDDY
      IF(IOUT.EQ.1)VIST(M,N)=VISTO(M)                                   EDDY
  240 CONTINUE                                                          EDDY
  200 CONTINUE                                                          EDDY
  500 CONTINUE                                                          EDDY
      RETURN                                                            EDDY
      END                                                               EDDY
      SUBROUTINE IMPY(IADD)                                             IMPY
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 IMPY
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                              IMPY
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3   IMPY
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7                      IMPY
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),          IMPY
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),                        IMPY
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     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),
     1 YSETA(55),AJS(55)
      COMMON/F9/INT(55),TE1(55),TE2(55),TE3(55),TE4(55)
      COMMON/F10/DT(61,55),DTM
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
      COMMON/F14/DAU(61,55,4),BDAU(55,4),BDAUS(55,4),TI(55,5),
     1CCIMPY,GM1,GM2,GM3,GM4,GM5
      QX(1,1;NXM)=GM5*T(1,1;NXM)
      QX(1,1;NXM)=VSQRT(QX(1,1;NXM);QX(1,1;NXM))
      SIGX(1,1;NXM)=.5*(U(1,1;NXM)*U(1,1;NXM)+V(1,1;NXM)*V(1,1;NXM))
      QY(1,1;NXM)=DTM/YETA(1,1;NXM)
      TAUXY(1,1;NXM)=GM4*VIS(1,1;NXM)*QY(1,1;NXM)/(RO(1,1;NXM)*
     1YETA(1,1;NXM))
      SIGY(1,1;NXM)=VABS(V(1,1;NXM);SIGY(1,1;NXM))
      AM(1,1,1;NXM)=SIGY(1,1;NXM)*QY(1,1;NXM)-.5
      SIGY(1,1;NXM)=(SIGY(1,1;NXM)+QX(1,1;NXM))*QY(1,1;NXM)-.5
      AM(1,1,2;NXM)=V(1,1;NXM)+QX(1,1;NXM)
      AM(1,1,2;NXM)=(VABS(AM(1,1,2;NXM);AM(1,1,2;NXM)))*QY(1,1;NXM)-.5
      AM(1,1,3;NXM)=V(1,1;NXM)-QX(1,1;NXM)
      AM(1,1,3;NXM)= VABS(AM(1,1,3;NXM);AM(1,1,3;NXM))*QY(1,1;NXM)-.5
      NIM=0
      NN1=2
      NN2=NS1M1
      IF(NSTRUT.EQ.0)NN2=N11
15    CONTINUE
      NIM=NIM+1
      DO 10 N=NN1,NN2
      DO 10 M=2,M11
      MM=(1-IADD)*M+IADD*(M11+2-M)
      IF(SIGY(MM,N).LT.0.)GO TO 10
      VV=V(MM,N)
      CC=QX(MM,N)
      ALP=SIGX(MM,N)
      RCCSQ=1./(CC*CC)
      UU=U(MM,N)
      RR=RO(MM,N)
      IF(IADD.EQ.0)GO TO 30
      IF(MM.NE.M11)GO TO 20
      DO 110 I=1,4
110   DAU(M11,N,I)=DAU(M11,N,I)+BDAU(N,I)*QY(M1,N)
      GO TO 20
30    CONTINUE
      IF(MM.NE.2)GO TO 20
      DO 230 I=1,4
230   DAU(2,N,I)=DAU(2,N,I)+BDAU(N,I)*QY(1,N)
20    CONTINUE
      DP=(ALP*DAU(MM,N,1)-UU*DAU(MM,N,2)-VV*DAU(MM,N,3)+DAU(MM,N,4))*GM1
      XX1=DAU(MM,N,1)-DP*RCCSQ
      XX2=(DAU(MM,N,2)-UU*DAU(MM,N,1))/RR
      XX3=-VV*CC*DAU(MM,N,1)+CC*DAU(MM,N,3)+DP
      XX4=-XX3+2.*DP
      VIS1=TAUXY(MM,N)+ABS(XX1)/(GM1*RR/GAMA)*CCIMPY
      DD1=AMAX1((VIS1+AM(MM,N,1)),0.)
      DD3=AMAX1((VIS1+AM(MM,N,2)),0.)
      DD4=AMAX1((VIS1+AM(MM,N,3)),0.)
      YY1=XX1/(1.+DD1)
      YY2=XX2/(1.+DD1)
      YY3=XX3/(1.+DD3)
```

```
      YY4=XX4/(1.+DD4)
      DR=YY1+.5*(YY3+YY4)*RCCSQ
      DAU(MM,N,1)=DR
      DAU(MM,N,2)=UU*DR+RR*YY2
      DAU(MM,N,3)=VV*DR+.5*(YY3-YY4)/CC
      DAU(MM,N,4)=ALP*DR+RR*UU*YY2+.5*(VV*(YY3-YY4)/CC+(YY3+YY4)/GM1)
      IF(M.EQ.M11)GO TO 10
      MJ=MM-2*IADD+1
      DD=YETA(MM,N)/YETA(MJ,N)
      ZZ1=DD*DD1*YY1
      ZZ2=DD*DD1*YY2
      ZZ3=DD*DD3*YY3
      ZZ4=DD*DD4*YY4
      DR=ZZ1+.5*(ZZ3+ZZ4)*RCCSQ
      DAU(MJ,N,1)=DAU(MJ,N,1)+DR
      DAU(MJ,N,2)=DAU(MJ,N,2)+UU*DR+ZZ2*RR
      DAU(MJ,N,3)=DAU(MJ,N,3)+VV*DR+.5*(ZZ3-ZZ4)/CC
      DAU(MJ,N,4)=DAU(MJ,N,4)+ALP*DR+RR*UU*ZZ2+.5*(VV*(ZZ3-ZZ4)/CC+
     1(ZZ3+ZZ4)/GM1)
   10 CONTINUE
      IF(NSTRUT.EQ.0)RETURN
      NN1=NS2P1
      NN2=N11
      IF(NIM.EQ.1)GO TO 15
      DO 5 N=NS1,NS2
      NN=N-NS1+1
    5 QYS(N)=DTM/YSETA(NN)
      DO 40 N=NS1,NS2
      DO 45 M=2,MS1
      MM=(1-IADD)*M+IADD*(MS1+2-M)
      IF(SIGY(MM,N).LT.0.)GO TO 45
      VV=V(MM,N)
      CC=QX(MM,N)
      ALP=SIGX(MM,N)
      RCCSQ=1./(CC*CC)
      UU=U(MM,N)
      RR=RO(MM,N)
      IF(IADD.EQ.0)GO TO 65
      IF(MM.NE.MS1)GO TO 60
      DO 70 I=1,4
   70 DAU(MS1,N,I)=DAU(MS1,N,I)+BDAUS(N,I)*QYS(N)
      GO TO 60
   65 CONTINUE
      IF(MM.NE.2)GO TO 60
      DO 75 I=1,4
   75 DAU(2,N,I)=DAU(2,N,I)+BDAU(N,I)*QY(1,N)
   60 CONTINUE
      DP=(ALP*DAU(MM,N,1)-UU*DAU(MM,N,2)-VV*DAU(MM,N,3)+DAU(MM,N,4))*GM1
      XX1=DAU(MM,N,1)-DP*RCCSQ
      XX2=(DAU(MM,N,2)-UU*DAU(MM,N,1))/RR
      XX3=-VV*CC*DAU(MM,N,1)+CC*DAU(MM,N,3)+DP
      XX4=-XX3+2.*DP
      VIS1=TAUXY(MM,N)+ABS(XX1)/(GM1*RR/GAMA)*CCIMPY
      DD1=AMAX1((VIS1+AM(MM,N,1)),0.)
      DD3=AMAX1((VIS1+AM(MM,N,2)),0.)
      DD4=AMAX1((VIS1+AM(MM,N,3)),0.)
      YY1=XX1/(1.+DD1)
      YY2=XX2/(1.+DD1)
      YY3=XX3/(1.+DD3)
      YY4=XX4/(1.+DD4)
      DR=YY1+.5*(YY3+YY4)*RCCSQ
      DAU(MM,N,1)=DR
      DAU(MM,N,2)=UU*DR+RR*YY2
      DAU(MM,N,3)=VV*DR+.5*(YY3-YY4)/CC
      DAU(MM,N,4)=ALP*DR+RR*UU*YY2+.5*(VV*(YY3-YY4)/CC+(YY3+YY4)/GM1)
      IF(M.EQ.MS1)GO TO 45
      MJ=MM-2*IADD+1
      DD=YETA(MM,N)/YETA(MJ,N)
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```
      ZZ1=DD*DD1*YY1                                                    IMPY
      ZZ2=DD*DD1*YY2                                                    IMPY
      ZZ3=DD*DD3*YY3                                                    IMPY
      ZZ4=DD*DD4*YY4                                                    IMPY
      DR=ZZ1+.5*(ZZ3+ZZ4)*RCCSQ                                         IMPY
      DAU(MJ,N,1)=DAU(MJ,N,1)+DR                                        IMPY
      DAU(MJ,N,2)=DAU(MJ,N,2)+UU*DR+ZZ2*RR                              IMPY
      DAU(MJ,N,3)=DAU(MJ,N,3)+VV*DR+.5*(ZZ3-ZZ4)/CC                     IMPY
      DAU(MJ,N,4)=DAU(MJ,N,4)+ALP*DR+RR*UU*ZZ2+.5*(VV*(ZZ3-ZZ4)/CC+     IMPY
     1(ZZ3+ZZ4)/GM1)                                                    IMPY
45     CONTINUE                                                         IMPY
      DO 50 M=MSP1,M11                                                  IMPY
      MM=(1-IADD)*M+IADD*(M11+MSP1-M)                                   IMPY
      IF(SIGY(MM,N).LT.0.)GO TO 50                                      IMPY
      VV=V(MM,N)                                                        IMPY
      CC=QX(MM,N)                                                       IMPY
      ALP=SIGX(MM,N)                                                    IMPY
      RCCSQ=1./(CC*CC)                                                  IMPY
      UU=U(MM,N)                                                        IMPY
      RR=RO(MM,N)                                                       IMPY
      IF(IADD.EQ.0)GO TO 85                                             IMPY
      IF(MM.NE.M11)GO TO 80                                             IMPY
      DO 90 I=1,4                                                       IMPY
90    DAU(M11,N,I)=DAU(M11,N,I)+BDAU(N,I)*QY(M1,N)                      IMPY
      GO TO 80                                                          IMPY
85    CONTINUE                                                          IMPY
      IF(MM.NE.MSP1)GO TO 80                                            IMPY
      DO 95 I=1,4                                                       IMPY
95    DAU(MSP1,N,I)=DAU(MSP1,N,I)+BDAUS(N,I)*QY(MS,N)                   IMPY
80    CONTINUE                                                          IMPY
      DP=(ALP*DAU(MM,N,1)-UU*DAU(MM,N,2)-VV*DAU(MM,N,3)+DAU(MM,N,4))*GM1IMPY
      XX1=DAU(MM,N,1)-DP*RCCSQ                                          IMPY
      XX2=(DAU(MM,N,2)-UU*DAU(MM,N,1))/RR                               IMPY
      XX3=-VV*CC*DAU(MM,N,1)+CC*DAU(MM,N,3)+DP                          IMPY
      XX4=-XX3+2.*DP                                                    IMPY
      VIS1=TAUXY(MM,N)+ABS(XX1)/(GM1*RR/GAMA)*CCIMPY                    IMPY
      DD1=AMAX1((VIS1+AM(MM,N,1)),0.)                                   IMPY
      DD3=AMAX1((VIS1+AM(MM,N,2)),0.)                                   IMPY
      DD4=AMAX1((VIS1+AM(MM,N,3)),0.)                                   IMPY
      YY1=XX1/(1.+DD1)                                                  IMPY
      YY2=XX2/(1.+DD1)                                                  IMPY
      YY3=XX3/(1.+DD3)                                                  IMPY
      YY4=XX4/(1.+DD4)                                                  IMPY
      DR=YY1+.5*(YY3+YY4)*RCCSQ                                         IMPY
      DAU(MM,N,1)=DR                                                    IMPY
      DAU(MM,N,2)=UU*DR+RR*YY2                                          IMPY
      DAU(MM,N,3)=VV*DR+.5*(YY3-YY4)/CC                                 IMPY
      DAU(MM,N,4)=ALP*DR+RR*UU*YY2+.5*(VV*(YY3-YY4)/CC+(YY3+YY4)/GM1)   IMPY
      IF(M.EQ.M11)GO TO 50                                              IMPY
      MJ=MM-2*IADD+1                                                    IMPY
      DD=YETA(MM,N)/YETA(MJ,N)                                          IMPY
      ZZ1=DD*DD1*YY1                                                    IMPY
      ZZ2=DD*DD1*YY2                                                    IMPY
      ZZ3=DD*DD3*YY3                                                    IMPY
      ZZ4=DD*DD4*YY4                                                    IMPY
      DR=ZZ1+.5*(ZZ3+ZZ4)*RCCSQ                                         IMPY
      DAU(MJ,N,1)=DAU(MJ,N,1)+DR                                        IMPY
      DAU(MJ,N,2)=DAU(MJ,N,2)+UU*DR+ZZ2*RR                              IMPY
      DAU(MJ,N,3)=DAU(MJ,N,3)+VV*DR+.5*(ZZ3-ZZ4)/CC                     IMPY
      DAU(MJ,N,4)=DAU(MJ,N,4)+ALP*DR+RR*UU*ZZ2+.5*(VV*(ZZ3-ZZ4)/CC+     IMPY
     1(ZZ3+ZZ4)/GM1)                                                    IMPY
50    CONTINUE                                                          IMPY
40    CONTINUE                                                          IMPY
      RETURN                                                            IMPY
      END                                                               IMPY
      SUBROUTINE VECIM2(IADD)                                           VECIM2
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1 VECIM2
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT                              VECIM2
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      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),
     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)
      COMMON/F5/AU(61,55,4),AM(61,55,4),AN(61,55,4),AU1(61,55,4)
      COMMON/F6/AUS(55,4),AMS(55,4),ANS(55,4),AUS1(55,4)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),
     1 YSETA(55),AJS(55)
      COMMON/F9/INT(55),TE1(55),TE2(55),TE3(55),TE4(55)
      COMMON/F10/DT(61,55),DTM
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
      COMMON/F14/DAU(61,55,4),BDAU(55,4),BDAUS(55,4),TI(55,5),
     1CCIMPY,GM1,GM2,GM3,GM4,GM5
C     *************************
      IF(IADD.EQ.1)GO TO 10
      K=M1
      GO TO 20
   10 K=1
   20 CONTINUE
      TI(1,1;N1)=Q8VGATHP(RO(K,1;NXM),M1,N1;TI(1,1;N1))
      TI(1,2;N1)=Q8VGATHP(U(K,1;NXM),M1,N1;TI(1,2;N11))
      TI(1,3;N1)=Q8VGATHP(V(K,1;NXM),M1,N1;TI(1,3;N1))
      TI(1,4;N1)=Q8VGATHP(T(K,1;NXM),M1,N1;TI(1,4;N1))
      TI(1,5;N1)=Q8VGATHP(VIS(K,1;NXM),M1,N1;TI(1,5;N1))
      IF(NSTRUT.EQ.0)GO TO 30
C
C     THE SUBROUTINE ASSUMES U=V=0 CONDITIONS ON THE
C     STRUT SURFACE.
C
      IF(IADD.EQ.1)GO TO 15
      DO 16 N=NS1,NS2
      NN=N-NS1+1
      ANS(N,1)=ROS(NN)
      ANS(N,2)=TS(NN)
   16 ANS(N,3)=VISS(NN)
      GO TO 30
   15 CONTINUE
      DO 17 N=NS1,NS2
      ANS(N,1)=RO(MS,N)
      ANS(N,2)=T(MS,N)
   17 ANS(N,3)=VIS(MS,N)
   30 CONTINUE
C     *************************
      RO(2,2;NXM4)=AU1(2,2,1;NXM4)/AJ(2,2;NXM4)
       U(2,2;NXM4)=AU1(2,2,2;NXM4)/AU1(2,2,1;NXM4)
       V(2,2;NXM4)=AU1(2,2,3;NXM4)/AU1(2,2,1;NXM4)
      QX(2,2;NXM4)=(U(2,2;NXM4)*U(2,2;NXM4)+V(2,2;NXM4)*V(2,2;NXM4))/2.
      SH(2,2;NXM4)=(AU1(2,2,4;NXM4)/AU1(2,2,1;NXM4)-QX(2,2;NXM4))*GAMA
      H(2,2;NXM4)=SH(2,2;NXM4)+QX(2,2;NXM4)
      P(2,2;NXM4)=GM2*RO(2,2;NXM4)*SH(2,2;NXM4)
      T(2,2;NXM4)=SH(2,2;NXM4)/CP
C     *************************
      CALL BOUND
C     *************************
      DO 40 N=2,N11
      ALP=.5*(TI(N,2)*TI(N,2)+TI(N,3)*TI(N,3))
      CC=SQRT(GM5*TI(N,4))
      AMS(N,1)=RO(K,N)-TI(N,1)
      AMS(N,2)=RO(K,N)*U(K,N)-TI(N,1)*TI(N,2)
      AMS(N,3)=RO(K,N)*V(K,N)-TI(N,1)*TI(N,3)
```

```
      AMS(N,4)=RO(K,N)*(GM3*T(K,N)+.5*(U(K,N)*U(K,N)+V(K,N)*V(K,N)))-
     1TI(N,1)*(GM3*TI(N,4)+ALP)
      DP=GM1*(ALP*AMS(N,1)-TI(N,2)*AMS(N,2)-TI(N,3)*AMS(N,3)+AMS(N,4))
      RCCSQ=1./(CC*CC)
      XX1=AMS(N,1)-DP*RCCSQ
      XX2=(AMS(N,2)-TI(N,2)*AMS(N,1))/TI(N,1)
      XX3=CC*(AMS(N,3)-TI(N,3)*AMS(N,1))+DP
      XX4=-XX3+2.*DP
      VIS1=GM4*TI(N,5)/(TI(N,1)*YETA(K,N))-.5*YETA(K,N)/DTM
      VABS1=ABS(TI(N,3))+VIS1
      VPCABS=ABS(TI(N,3)+CC)+VIS1
      VMCABS=ABS(TI(N,3)-CC)+VIS1
      DD1=AMAX1(VABS1,0.)
      DD3=AMAX1(VPCABS,0.)
      DD4=AMAX1(VMCABS,0.)
      YY1=DD1*XX1
      YY2=DD1*XX2
      YY3=DD3*XX3
      YY4=DD4*XX4
      AY1=(YY3+YY4)/2.
      AY2=(YY3-YY4)/(2.*CC)
      BDAU(N,1)=YY1+AY1*RCCSQ
      BDAU(N,2)=TI(N,2)*BDAU(N,1)+TI(N,1)*YY2
      BDAU(N,3)=TI(N,3)*BDAU(N,1)+AY2
      BDAU(N,4)=ALP*BDAU(N,1)+TI(N,1)*TI(N,2)*YY2+TI(N,3)*AY2+AY1/GM1
   40 CONTINUE
      IF(NSTRUT.EQ.0)RETURN
      IF(IADD.EQ.1)GO TO 55
      DO 50 N=NS1,NS2
      NN=N-NS1+1
      TE1(N)=ROS(NN)
      TE2(N)=TS(NN)
   50 TE3(N)=YSETA(NN)
      GO TO 60
   55 CONTINUE
      DO 56 N=NS1,NS2
      TE1(N)=RO(MS,N)
      TE2(N)=T(MS,N)
   56 TE3(N)=YETA(MS,N)
   60 CONTINUE
      DO 65 N=NS1,NS2
      BDAUS(N,1)=TE1(N)-ANS(N,1)
      BDAUS(N,4)=GM3*(TE1(N)*TE2(N)-ANS(N,1)*ANS(N,2))
      VIS1=GM4*ANS(N,3)/(ANS(N,1)*TE3(N))-.5*TE3(N)/DTM
      TE4(N)=SQRT(GM5*ANS(N,2))
      TI(N,1)=AMAX1(VIS1,0.)
      TI(N,2)=AMAX1(VIS1+TE4(N),0.)
      BDAUS(N,1)=TI(N,1)*BDAUS(N,1)-GM1/(TE4(N)*TE4(N))*(TI(N,1)-TI(N,2)
     1)*BDAUS(N,4)
      BDAUS(N,4)=TI(N,2)*BDAUS(N,4)
   65 CONTINUE
C     *************************
      RETURN
      END
      SUBROUTINE SPILL(SWEEP)
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),
     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F4/SIGX(61,55),SIGY(61,55),TAUXY(61,55),QX(61,55),
     1 QY(61,55),SIGXS(55),SIGYS(55),TAUXYS(55),QXS(55),QYS(55)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),
     1 YSETA(55),AJS(55)
```

```
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
      DIMENSION XP(61,55),USP(61,55),UST1(55),USP1(55)
      DIMENSION FMASS(55),UST(61,55),FMAST(55)
      PI=4.*ATAN(1.)
      THESW=SWEEP*PI/180.
      CTHESW=COS(THESW)
      STHESW=SIN(THESW)
      FMS= FM/CTHESW
      XP(1,1;NXM)=X(1,1;NXM)/CTHESW
      VT=FMS*SQRT(GAMA*RGAS*TF)*STHESW*CTHESW
      UST(1,1;NXM)=VT
      UST1(1;NS)=VT
      IF(NFLOW.EQ.0)GO TO 35
      QX(1,1;NXM)=VABS(U(1,1;NXM);QX(1,1;NXM))
C
C     IN M112=M1-12, 12 IS AN ARBITRARY NUMBER. WHAT IT MEANS IS THAT
C     FIRST 12 POINTS LIE IN THE B.L.PROFILE.  THIS IS REQUIRED TO PUT
C     VISCOUS EFFECTS ON THE INVISCID COMPONENT VT.  NUMBER 12 MAY
C     NEED TO BE CHANGED FOR CERTAIN CALCULATIONS.
C
      M112=M1-12
      DO 30 N=1,N1
      DO 30 M=M112,M1
   30 UST(M,N)=VT*QX(M,N)/QX(M112,N)
      IF(NSTRUT.EQ.0)GO TO 45
      QXS(1;NS)=VABS(US(1;NS);QXS(1;NS))
      MS11=MS+11
      DO 40 N=NS1,NS2
      DO 40 M=MS,MS11
   40 UST(M,N)=VT*QX(M,N)/QX(MS11,N)
      MS10=MS-10
      DO 50 N=NS1,NS2
      NN=N-NS1+1
      DO 50 M=MS10,MS1
      QYS(NN)=QX(MS10,N)
   50 UST(M,N)=VT*QX(M,N)/QX(MS10,N)
      UST1(1;NS)=VT*QXS(1;NS)/QYS(1;NS)
      USP1(1;NS)=UST1(1;NS)-US(1;NS)*STHESW
   45 CONTINUE
      IF(NCWL.EQ.0)GO TO 35
      DO 55 N=NCWL1,NCWL2
      DO 55 M=1,12
   55 UST(M,N)=VT*QX(M,N)/QX(12,N)
   35 CONTINUE
      USP(1,1;NXM)=UST(1,1;NXM)-U(1,1;NXM)*STHESW
      NSM=NS1M1
      IF(NSTRUT.EQ.0)NSM=N1
      FMASS(1;N1)=0.
      DO 275 N=1,NSM
      DO 275 M=2,M1
      FMASS(N)=FMASS(N)+(RO(M-1,N)*USP(M-1,N)+RO(M,N)*USP(M,N))*(Y(M,N)-
     1Y(M-1,N))/2.
  275 CONTINUE
      IF(NSTRUT.EQ.0)GO TO 290
      DO 280 N=NS2P1,N1
      DO 280 M=2,M1
      FMASS(N)=FMASS(N)+(RO(M-1,N)*USP(M-1,N)+RO(M,N)*USP(M,N))*(Y(M,N)-
     1Y(M-1,N))/2.
  280 CONTINUE
      DO 250 N=NS1,NS2
      DO 255 M=2,MS1
      FMASS(N)=FMASS(N)+(RO(M-1,N)*USP(M-1,N)+RO(M,N)*USP(M,N))*(Y(M,N)-
     1Y(M-1,N))/2.
  255 CONTINUE
      DO 260 M=MSP1,M1
      FMASS(N)=FMASS(N)+(RO(M-1,N)*USP(M-1,N)+RO(M,N)*USP(M,N))*(Y(M,N)-
```

```
     1Y(M-1,N))/2.
260   CONTINUE
      NN=N-NS1+1
      FMASS(N)=FMASS(N)+(ROS(NN)*USP1(NN)+
     1RO(MS1,N)*USP(MS1,N))*(YS(NN)-Y(MS1,N))/2.
250    CONTINUE
290   CONTINUE
      FMAST(1)=FMASS(1)
      DO 285 N=2,N1
      FMAST(N)=FMAST(N-1)+(FMASS(N)+FMASS(N-1))*(XP(1,N)-XP(1,N-1))/2.
285   CONTINUE
      WRITE(6,300)(N,XP(1,N),FMASS(N),FMAST(N),N=1,N1)
300   FORMAT(10X,'BODY STATION NO.=',I4,3X,'XP=',F10.6,3X,'LOCAL MASS SP
     1ILLED=',F10.5,3X,'TOTAL MASS SPILLED UPTO XP=',F10.5)
      QX(1,1;NXM)=P(1,1;NXM)/P(1,1)
      WRITE(6,805)
      WRITE(6,810)(N,XP(1,N),QX(1,N),QX(M1,N),N=1,N1)
805   FORMAT(///,5X,'N',16X,'XP',21X,'CENTER LINE PR. RATIO',
     120X,'SIDEWALL PR. RATIO',/)
810   FORMAT(4X,I3,7X,F13.5,20X,F15.4,20X,F15.4)
      IF(NSTRUT.EQ.0)GO TO 20
      QXS(NS1;NS)=PS(1;NS)/P(1,1)
      WRITE(6,806)
      WRITE(6,810)(N,XP(MS,N),QX(MS,N),QXS(N),N=NS1,NS2)
20    CONTINUE
806   FORMAT(///,5X,'N',16X,'XP',16X,'STRUT UPPER SURFACE PR. RATIO',
     116X,'STRUT LOWER SURFACE PR. RATIO',/)
      RETURN
      END
      SUBROUTINE PRINT
      BIT B1
      COMMON/F1/NXM,NXM1,NXM2,NXM3,NXM4,N1,M1,N11,M11,NS1,NS2,NS,MS,MS1
     1,NCWL,NCWL1,NCWL2,NCWLM,NCWLP,NSTRUT
      COMMON/FA1/M12,M13,N12,N13,NXM5,NXM6,MS2,MS3,MS4,MSP1,MSP2,MSP3
     1,NSM1,NS1P1,NS2M1,NS1M1,NS2P1,NNS,NS1M2,NXM7
      COMMON/F2/RO(61,55),U(61,55),V(61,55),P(61,55),T(61,55),
     1 SH(61,55),H(61,55),ROS(55),US(55),VS(55),
     2 PS(55),TS(55),SHS(55),HS(55)
      COMMON/F3/VISL(61,55),VIST(61,55),VIS(61,55),VISS(55)
      COMMON/F7/X(61,55),Y(61,55),XXI(61,55),YXI(61,55),
     1 XETA(61,55),YETA(61,55),AJ(61,55)
      COMMON/F8/XS(55),YS(55),XSXI(55),YSXI(55),XSETA(55),
     1 YSETA(55),AJS(55)
      COMMON/F11/ERRO(61,55),B1(61,55)
      COMMON/F12/LSYM,NFLOW,LFI,LFO,ILT,LMAX,LW,LEXIT,CRIT,FDT,FDTL,
     1 TIME,CCP,CCT,L,LK,TIMEL,CRITAVG
      COMMON/F13/GAMA,RGAS,CP,PR,PRT,CVIS,FM,PF,TF,UF,ROF,SHF,HF
      WRITE(6,500)L,TIME,TIMEL
      WRITE(6,505) CCP,CCT,FDT,FDTL
      WRITE(6,510) CRIT,CRITAVG,LEXIT
      DO 250 N=1,N1
      WRITE(6,545)N
      WRITE(6,550)
      DO 250 MM=1,M1
      M=M1-MM+1
      WRITE(6,560)X(M,N),Y(M,N),U(M,N),V(M,N),P(M,N),T(M,N),RO(M,N),
     1SH(M,N),VIST(M,N),ERRO(M,N)
250   CONTINUE
      IF(NSTRUT.EQ.0)GO TO 255
      WRITE(6,570)
      WRITE(6,560)(XS(N),YS(N),US(N),VS(N),PS(N),TS(N),ROS(N),SHS(N),
     1HS(N),VISS(N),N=1,NS)
255   CONTINUE
      ERRO(1,1;NXM)=RO(1,1;NXM)*U(1,1;NXM)
      DO 265 N=1,N1
      FMASS=0.
      IF(NSTRUT.EQ.0)GO TO 261
      IF(N.LT.NS1.OR.N.GT.NS2)GO TO 261
```

```
      NN=N-NS1+1
      DO 263 M=2,MS1
263    FMASS=FMASS+(ERRO(M,N)+ERRO(M-1,N))/2.*(Y(M,N)-Y(M-1,N))
      FMASS=FMASS+(ERRO(MS1,N)+ROS(NN)*US(NN))/2.*(YS(NN)-Y(MS1,N))
      DO 262 M=MSP1,M1
262    FMASS=FMASS+(ERRO(M,N)+ERRO(M-1,N))/2.*(Y(M,N)-Y(M-1,N))
      GO TO 264
261   CONTINUE
      DO 260 M=2,M1
260    FMASS=FMASS+(ERRO(M,N)+ERRO(M-1,N))/2.*(Y(M,N)-Y(M-1,N))
264   CONTINUE
      WRITE(6,700)N,X(1,N),FMASS
265    CONTINUE
500   FORMAT(/,2X,'NO. OF ITERATIONS =',I5,2X,'TIME =',E15.7,
     1       2X,'TIME LIMIT=',E15.7)
 505  FORMAT(/,10X,'CCP=',F8.4,10X,'CCT=',F8.4,10X,'FDT=',F8.4,10X,
     1       'FDTL=',F8.4,/)
 510  FORMAT(/,1X,'LOCAL ERROR CRITERION=',F10.5,5X,
     1             'AVERAGE ERROR CRITERION=',F11.7,5X,
     1             'ORDER OF EXTRAPOLATION AT OUTFLOW =',I2)
545   FORMAT(/,10X,'BODY STATION NO.=',I3,/)
550   FORMAT(/,6X,'X',9X,'Y',11X,'U',12X,'V',12X,'P',12X,'T',10X,'RO',
     113X,'SH',11X,'VIST',5X,'ERRO')
560   FORMAT(1X, 2F9.6,2F12.5,F14.5,F13.5,F11.5,F14.5,F15.6,F10.6)
570   FORMAT(/,5X,'XS',8X,'YS',10X,'US',11X,'VS',11X,'PS',11X,'TS',10X,
     1'ROS',11X,'SHS',11X,'HS',9X,'VISS')
700   FORMAT(/,10X,'BODY STATION NO.=',I3,10X,'X(METERS)=',F9.5,10X,
     1'MASS FLOW RATE(KG/M/SEC)=',F10.5)
      RETURN
      END
```

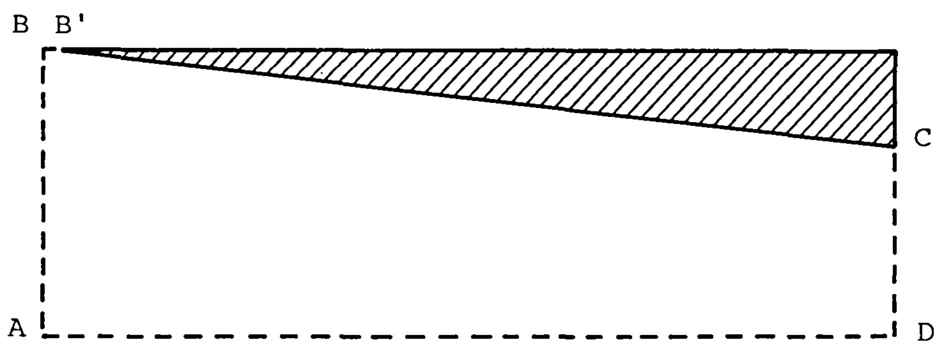
APPENDIX B

EXAMPLES OF GEOMETRIES AND ASSOCIATED PARAMETERS

Nonsymmetric Problems

Examples of geometries and associated parameters for nonsymmetric problems are as follows:

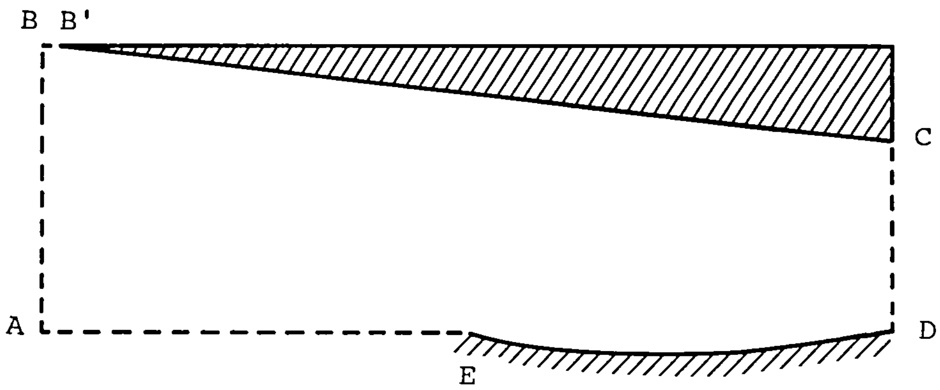
Example 1



A:	N = 1, M = 1	N1 = 61
B:	N = 1, M = M1	M1 = 51
B':	N = 2, M = M1	SWEEP = 0
C:	N = N1, M = M1	NSTRUT = 0
D:	N = N1, M = 1	LSYM = 0
		NCWL = 0

FOR NFLOW = 2: CALL EDDY (2,N1,1,M1,1,0)

Example 2

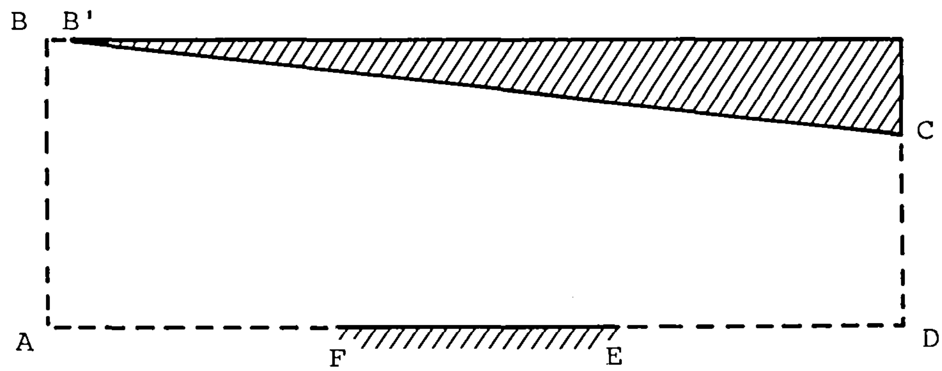


A:	N = 1,	M = 1
B:	N = 1,	M = M1
B':	N = 2,	M = M1
C:	N = N1,	M = M1
D:	N = N1,	M = 1
E:	N = 31,	M = 1

N1 = 61
M1 = 51
SWEEP = 0
NSTRUT = 0
LSYM = 0
NCWL = 1
NCWL1 = 31
NCWL2 = N1

```
FOR NFLOW = 2:  CALL EDDY (2,30,1,M1,1,0)
                CALL EDDY (31,N1,1,M1,2,0)
```

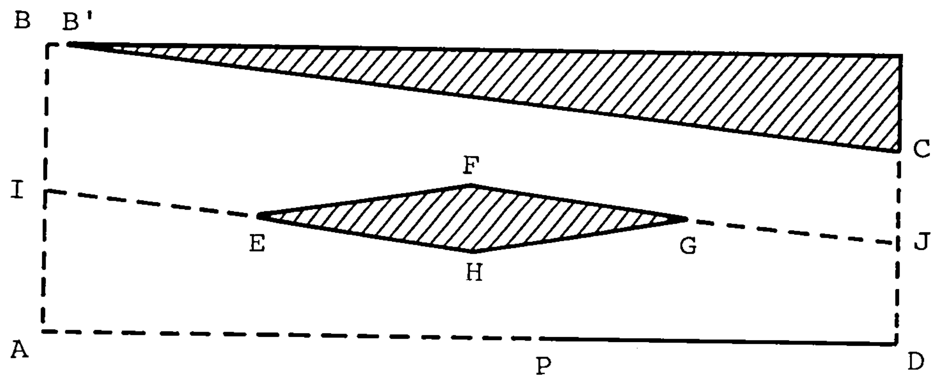
Example 3




```
A:   N = 1,   M = 1                      N1 = 61
B:   N = 1,   M = M1                     M1 = 51
B':  N = 2,   M = M1                  SWEEP = 0
C:   N = N1,  M = M1                 NSTRUT = 0
D:   N = N1,  M = 1                    LSYM = 0
E:   N = 41,  M = 1                    NCWL = 1
F:   N = 21,  M = 1                   NCWL1 = 21
                                      NCWL2 = 41

FOR NFLOW = 2:  CALL EDDY (2,20,1,M1,1,0)
                CALL EDDY (21,41,1,M1,2,0)
                CALL EDDY (42,N1,1,M1,1,0)
```

Example 4



A: N = 1, M = 1
B: N = 1, M = M1
B': N = 2, M = M1
C: N = N1, M = M1
D: N = N1, M = 1
P: N = 36, M = 1
I: N = 1, M = 26
E: N = 16, M = 26
F: N = 31, M = 26
G: N = 46, M = 26
H: N = 46, M = 26
J: N = N1, M = 26

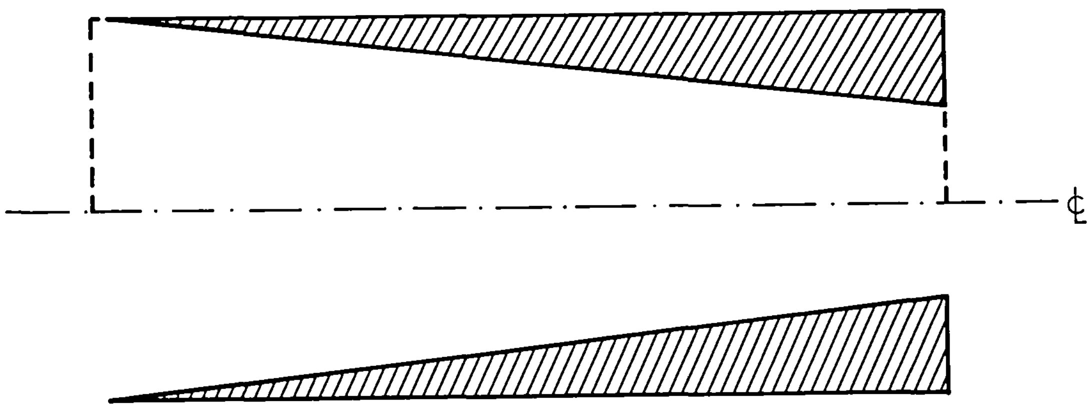
N1 = 61
M1 = 51
SWEEP = 0
NSTRUT = 1
NS1 = 16
NS2 = 46
MS = 26
LSYM = 0
NCWL = 1
NCWL1 = 36
NCWL2 = N1

```
FOR NFLOW = 2:   CALL EDDY (2,15,1,M1,1,0)
                 CALL EDDY (16,46,MS,M1,2,0)
                 CALL EDDY (47,N1,1,M1,2,0)
                 CALL EDDY (16,35,1,MS1,1,1)
                 CALL EDDY (36,46,1,MS1,2,1)
```

Symmetric Problems

The code solves only the upper half of the flow for symmetric problems. Examples of geometries and associated parameters for symmetric problems are as follows:

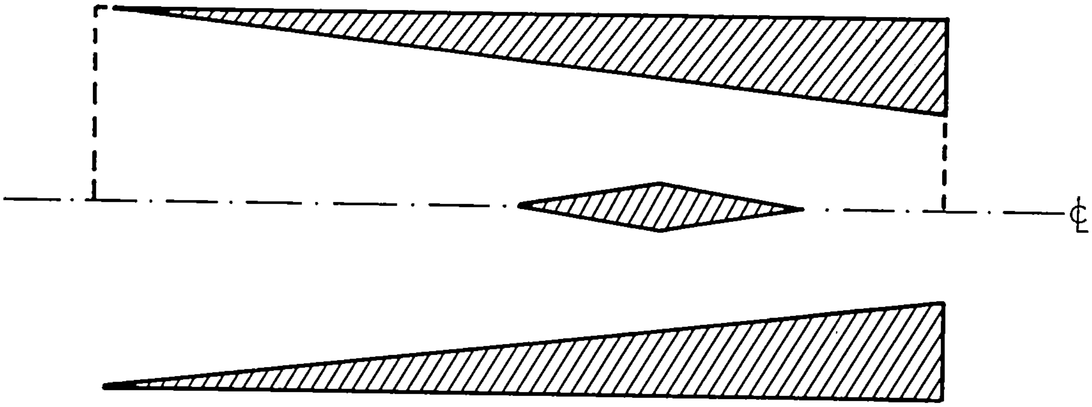
Example 1



```
     N1 = 61
     M1 = 51
  SWEEP = 0
 NSTRUT = 0
   LSYM = 1
   NCWL = 0

FOR NFLOW = 2:  CALL EDDY (2,N1,1,M1,1,0)
```

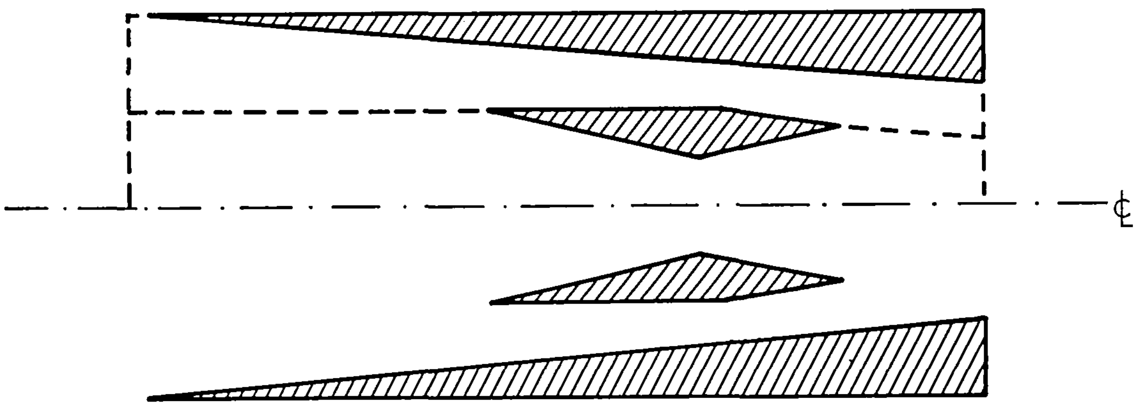
Example 2



```
    N1 = 61
    M1 = 51
 SWEEP = 0
NSTRUT = 0
  LSYM = 1
  NCWL = 1
 NCWL1 = 31
 NCWL2 = 51

FOR NFLOW = 2:  CALL EDDY (2,30,1,M1,1,0)
                CALL EDDY (31,51,1,M1,2,0)
                CALL EDDY (52,N1,1,M1,1,0)
```

Example 3



```
     N1 = 61
     M1 = 51
  SWEEP = 0
 NSTRUT = 1
    NS1 = 26
    NS2 = 51
     MS = 27
   LSYM = 1
   NCWL = 0

FOR NFLOW = 2:  CALL EDDY (2,25,1,M1,1,0)
                CALL EDDY (26,51,MS,M1,2,0)
                CALL EDDY (26,51,1,MS1,1,1)
                CALL EDDY (52,N1,1,M1,1,0)
```

The sample problem discussed in this report provides another example of the type of geometries that can be analyzed with the present code.

APPENDIX C

USE OF PARAMETER LKK

In this appendix, several examples are given for the use of parameter LKK in trying more than one value of time-step parameter FDT or damping coefficients CCP and CCT during one computer run. For a given problem, it may be that the calculations become unstable (i.e., a negative temperature occurs in the flow field) for one particular value of, say, FDT, and the user may have to try several values before he finds the right value of FDT for which the calculations remain stable. The same thing may have to be done with CCP and CCT. One way to find the right values of FDT and CCP and CCT would be to submit several runs with a particular set of values of these parameters, but to avoid this, the code has a parameter LKK at line NASCRIN 224 that allows the user to try several values of FDT or CCP and CCT in one run of the code. To do so, the user has to change lines NASCRIN 219 through NASCRIN 224 as illustrated in the following examples:

Example 1

```
       FDT = 1.
       CCP = 0.
1000   CONTINUE
       LKK = LKK + 1
       CCP = CCP + 0.1
       CCT = CCP
       IF(LKK.EQ.6)STOP
```

The code begins calculations with FDT = 1 and CCP = CCT = 0.1. If the calculations develop a negative temperature in the field, the code stops, prints out the flow-field variables at each grid point, and then returns to statement 1000. It is restarted with FDT = 1 and CCP = CCT = 0.2. If the calculations remain stable, the code will terminate in a normal way either on a convergence criterion or on LMAX without trying any more values of CCP and CCT. But, if a negative temperature develops again in the flow field, the calculations will restart with FDT = 1 and CCP = CCT = 0.3. For this example, the code will try five values of the damping coefficients in increments of 0.1 before stopping. The number of attempts is determined from the statement

```
       IF(LKK.EQ.6)STOP
```

and is always one less than the number in parentheses (in this case, it is 6 - 1 = 5).

Example 2

```
       FDT = 1.
       CCP = 0.5
1000   CONTINUE
       LKK = LKK + 1
       CCT = CCP
       FDT = FDT - 0.1
       IF(LKK.EQ.4)STOP
```

This example allows the user to try three values of FDT, namely 0.9, 0.8, and 0.7, with a constant value of CCP = CCT = 0.5.

Example 3

```
      FDT = 0.9
      CCP = 0.5
 1000 CONTINUE
      LKK = LKK + 1
      CCT = CCP
      IF(LKK.EQ.2)STOP
```

This example uses only one set of values of FDT, CCP, and CCT, namely FDT = 0.9 and CCP = CCT = 0.5.

If the code develops a negative temperature very early in the calculations, the chances are that the value of FDT needs to be reduced. But if the negative temperature occurs after several hundred time-steps, it may be caused by insufficient damping. This may not always be true but provides the user with a guideline in changing FDT, CCP, and CCT. Also, if the user wants to try several values of FDT, he should start from a higher value and decrease it gradually so that the allowable time-step is as large as possible. On the other hand, to keep the damping contribution as small as possible, the user should start with smaller values of CCP and CCT and gradually increase them.

APPENDIX D

ADJUSTMENT OF TIME-STEP AND DAMPING COEFFICIENTS

In this appendix, examples are presented to show how to gradually increase FDT or decrease CCP and CCT over a number of time-steps from their initial values.

Example 1

Suppose the calculations are started with FDT = 0.5, and the user wants to increase it to 0.9 over 1000 time-steps. This can be done by inserting the following lines after line VISCOUS 51 for viscous flow calculations or after line INVICID 60 for inviscid flow calculations:

```
IF(L.GT.1000)GO TO 400
FDT = FDT + ((0.9 - 0.5)/1000)*2.
400 CONTINUE
```

The factor 2 in the expression for FDT occurs because the change in FDT is made after every two time-steps. By inserting the above three lines, FDT will change from 0.5 to 0.9 in 1000 time-steps. FDT will then remain constant at 0.9 for subsequent time-steps.

Example 2

In the second example, suppose the user wants to use a damping coefficient of 0.7 for the first 1000 time-steps and then wants to reduce it to 0.5 over the next 2000 time-steps. This can be done by inserting the following lines in the code at the locations discussed in the previous example:

```
IF(L.GT.3000)GO TO 400
IF(L.LT.1000)GO TO 400
CCP = CCP - ((0.7 - 0.5)/2000)*2
CCT = CCP
400 CONTINUE
```

These statements change the damping coefficients from 0.7 to 0.5 between time-steps 1000 to 3000. The damping coefficients remain constant at 0.5 thereafter.

APPENDIX E

SAMPLE OUTPUTS

Geometry Output

N	M	X	Y	XXI	XETA	YXI	YETA	AJ
1	61	.00000000	.04000000	.00500000	.00000000	.00000000	.00002055	.00000010
1	60	.00000000	.03997510	.00500000	.00000000	.00000000	.00002983	.00000015
1	59	.00000000	.03993897	.00500000	.00000000	.00000000	.00004324	.00000022
1	58	.00000000	.03988665	.00500000	.00000000	.00000000	.00006259	.00000031
1	57	.00000000	.03981099	.00500000	.00000000	.00000000	.00009040	.00000045
1	56	.00000000	.03970187	.00500000	.00000000	.00000000	.00013018	.00000065
1	55	.00000000	.03954509	.00500000	.00000000	.00000000	.00018662	.00000093
1	54	.00000000	.03932106	.00500000	.00000000	.00000000	.00026582	.00000133
1	53	.00000000	.03900339	.00500000	.00000000	.00000000	.00037522	.00000188
1	52	.00000000	.03855786	.00500000	.00000000	.00000000	.00052288	.00000261
1	51	.00000000	.03794250	.00500000	.00000000	.00000000	.00071578	.00000358
1	50	.00000000	.03711035	.00500000	.00000000	.00000000	.00095622	.00000478
1	49	.00000000	.03601659	.00500000	.00000000	.00000000	.00123655	.00000618
1	48	.00000000	.03463154	.00500000	.00000000	.00000000	.00153337	.00000767
1	47	.00000000	.03295800	.00500000	.00000000	.00000000	.00180529	.00000903
1	46	.00000000	.03104684	.00500000	.00000000	.00000000	.00199974	.00001000
1	45	.00000000	.02900000	.00500000	.00000000	.00000000	.00207073	.00001035
1	44	.00000000	.02695316	.00500000	.00000000	.00000000	.00199974	.00001000
1	43	.00000000	.02504200	.00500000	.00000000	.00000000	.00180529	.00000903
1	42	.00000000	.02336846	.00500000	.00000000	.00000000	.00153337	.00000767
1	41	.00000000	.02198341	.00500000	.00000000	.00000000	.00123655	.00000618
1	40	.00000000	.02088965	.00500000	.00000000	.00000000	.00095622	.00000478
1	39	.00000000	.02005750	.00500000	.00000000	.00000000	.00071578	.00000358
1	38	.00000000	.01944214	.00500000	.00000000	.00000000	.00052288	.00000261
1	37	.00000000	.01899661	.00500000	.00000000	.00000000	.00037522	.00000188
1	36	.00000000	.01867894	.00500000	.00000000	.00000000	.00026582	.00000133
1	35	.00000000	.01845491	.00500000	.00000000	.00000000	.00018662	.00000093
1	34	.00000000	.01829813	.00500000	.00000000	.00000000	.00013018	.00000065
1	33	.00000000	.01818901	.00500000	.00000000	.00000000	.00009040	.00000045
1	32	.00000000	.01811335	.00500000	.00000000	.00000000	.00006259	.00000031
1	31	.00000000	.01806103	.00500000	.00000000	.00000000	.00004324	.00000022
1	30	.00000000	.01802490	.00500000	.00000000	.00000000	.00002963	.00000015
1	29	.00000000	.01800000	.00500000	.00000000	.00000000	.00002443	.00000012
1	28	.00000000	.01797604	.00500000	.00000000	.00000000	.00002941	.00000015
1	27	.00000000	.01793941	.00500000	.00000000	.00000000	.00004494	.00000022
1	26	.00000000	.01788348	.00500000	.00000000	.00000000	.00006853	.00000034
1	25	.00000000	.01779835	.00500000	.00000000	.00000000	.00010416	.00000052
1	24	.00000000	.01766927	.00500000	.00000000	.00000000	.00015752	.00000079
1	23	.00000000	.01747481	.00500000	.00000000	.00000000	.00023643	.00000118
1	22	.00000000	.01718460	.00500000	.00000000	.00000000	.00035085	.00000175
1	21	.00000000	.01675752	.00500000	.00000000	.00000000	.00051199	.00000256
1	20	.00000000	.01614187	.00500000	.00000000	.00000000	.00072909	.00000365
1	19	.00000000	.01528027	.00500000	.00000000	.00000000	.00100279	.00000501
1	18	.00000000	.01412311	.00500000	.00000000	.00000000	.00131509	.00000658
1	17	.00000000	.01265206	.00500000	.00000000	.00000000	.00162060	.00000810
1	16	.00000000	.01090722	.00500000	.00000000	.00000000	.00185017	.00000925
1	15	.00000000	.00900000	.00500000	.00000000	.00000000	.00193626	.00000968
1	14	.00000000	.00709278	.00500000	.00000000	.00000000	.00185017	.00000925
1	13	.00000000	.00534794	.00500000	.00000000	.00000000	.00162060	.00000810
1	12	.00000000	.00387689	.00500000	.00000000	.00000000	.00131509	.00000658
1	11	.00000000	.00271973	.00500000	.00000000	.00000000	.00100279	.00000501
1	10	.00000000	.00185813	.00500000	.00000000	.00000000	.00072909	.00000365
1	9	.00000000	.00124248	.00500000	.00000000	.00000000	.00051199	.00000256
1	8	.00000000	.00081540	.00500000	.00000000	.00000000	.00035085	.00000175
1	7	.00000000	.00052519	.00500000	.00000000	.00000000	.00023643	.00000118
1	6	.00000000	.00033073	.00500000	.00000000	.00000000	.00015752	.00000079
1	5	.00000000	.00020165	.00500000	.00000000	.00000000	.00010416	.00000052
1	4	.00000000	.00011652	.00500000	.00000000	.00000000	.00006853	.00000034
1	3	.00000000	.00006059	.00500000	.00000000	.00000000	.00004494	.00000022
1	2	.00000000	.00002396	.00500000	.00000000	.00000000	.00002941	.00000015
1	1	.00000000	.00000000	.00500000	.00000000	.00000000	.00001922	.00000010

APPENDIX E

Geometry Output for Lower Surface of Strut

The geometry output for the lower surface of the strut is printed only for NSTRUT = 1.

N	M	X	Y	XXI	XETA	YXI	YETA	AJ
1	29	.05500000	.01800000	.00250000	.00000000	-.00016457	.00001922	.00000005
2	29	.05750000	.01767087	.00250000	-.00000000	-.00032913	.00001887	.00000005
3	29	.06000000	.01734174	.00250000	-.00000000	-.00032913	.00001852	.00000005
4	29	.06250000	.01701261	.00250000	-.00000000	-.00032913	.00001816	.00000005
5	29	.06500000	.01668348	.00250000	.00000000	-.00032913	.00001781	.00000004
6	29	.06750000	.01635434	.00250000	.00000000	-.00032913	.00001746	.00000004
7	29	.07000000	.01602521	.00250000	.00000000	-.00032913	.00001711	.00000004
8	29	.07250000	.01569608	.00250000	-.00000000	-.00032913	.00001676	.00000004
9	29	.07500000	.01536695	.00250000	.00000000	-.00032913	.00001641	.00000004
10	29	.07750000	.01503782	.00250000	.00000000	-.00032913	.00001570	.00000004
11	29	.08000000	.01470869	.00250000	.00000000	-.00032913	.00001500	.00000004
12	29	.08250000	.01437956	.00250000	-.00000000	-.00032913	.00001430	.00000004
13	29	.08500000	.01405043	.00250000	.00000000	-.00032913	.00001360	.00000003
14	29	.08750000	.01372129	.00250000	.00000000	-.00032913	.00001289	.00000003
15	29	.09000000	.01339216	.00250000	-.00000000	-.00032913	.00001219	.00000003
16	29	.09250000	.01306303	.00250000	-.00000000	-.00032913	.00001149	.00000003
17	29	.09500000	.01273390	.00250000	.00000000	-.00032913	.00001078	.00000003
18	29	.09750000	.01240477	.00250000	.00000000	-.00032913	.00001008	.00000003
19	29	.10000000	.01207564	.00250000	-.00000000	-.00002720	.00000938	.00000002
20	29	.10250000	.01235037	.00250000	-.00000000	.00027473	.00001002	.00000003
21	29	.10500000	.01262510	.00250000	.00000000	.00027473	.00001067	.00000003
22	29	.10750000	.01289983	.00250000	-.00000000	.00027473	.00001131	.00000003
23	29	.11000000	.01317456	.00250000	-.00000000	.00027473	.00001196	.00000003
24	29	.11250000	.01344929	.00250000	-.00000000	.00027473	.00001260	.00000003
25	29	.11500000	.01372402	.00250000	.00000000	.00027473	.00001325	.00000003
26	29	.11750000	.01399875	.00250000	-.00000000	.00027473	.00001389	.00000003
27	29	.12000000	.01427348	.00250000	-.00000000	.00027473	.00001454	.00000004
28	29	.12250000	.01454821	.00250000	-.00000000	.00027473	.00001518	.00000004
29	29	.12500000	.01482293	.00250000	-.00000000	.00027473	.00001583	.00000004
30	29	.12750000	.01509766	.00250000	.00000000	.00027473	.00001612	.00000004
31	29	.13000000	.01537239	.00250000	.00000000	.00000557	.00001641	.00000004

APPENDIX E

Flow-Field Output

```
L=20700     MAX.ERROR=  .13830E-03     MEAN SQRT ERROR=  .16545E-06
L=20750     MAX.ERROR=  .30886E-03     MEAN SQRT ERROR=  .26362E-06
L=20800     MAX.ERROR=  .15369E-03     MEAN SQRT ERROR=  .20901E-06
L=20850     MAX.ERROR=  .29912E-03     MEAN SQRT ERROR=  .31551E-06
L=20900     MAX.ERROR=  .25054E-03     MEAN SQRT ERROR=  .25941E-06
L=20950     MAX.ERROR=  .29888E-03     MEAN SQRT ERROR=  .26156E-06
NO. OF ITERATIONS =20966  TIME =  .2635594E-03  TIME LIMIT=  .2635454E-03

CCP=  .5000     CCI=  .5000     EDI=  1.0000     EDTI=  1.0000

LOCAL ERROR CRITERION=  .00010   AVERAGE ERROR CRITERION=  .0000001   ORDER OF EXTRAPOLATION AT OUTFLOW = 1
     BODY STATION NO.= 27
```

X	Y	U	V	P	T	RO	SH	VIST	ERRO
.082500	.031854	.00000	.00000	21117.65277	1439.40576	.05112	1445883.08563	.000000	.000000
.082500	.031839	141.43285	-16.06448	21117.65277	1439.40576	.05112	1445883.08563	.000000	.000000
.082500	.031816	336.07852	-36.45959	21090.51808	1420.07701	.05175	1426467.36132	.000002	.000000
.082500	.031783	578.87778	-64.58265	21170.87359	1358.09297	.05432	1364204.38656	.000017	.000000
.082500	.031735	805.29764	-85.39118	21015.02646	1250.47902	.05856	1256106.17466	.000069	.000000
.082500	.031667	986.43322	-109.12013	21268.45406	1127.02993	.06575	1132101.56738	.000198	.000000
.082500	.031568	1113.72752	-118.74615	20912.22281	1022.32666	.07127	1026927.13113	.000385	.000000
.082500	.031427	1240.94851	-138.72676	21389.75892	905.14341	.08234	909216.55292	.000445	.000000
.082500	.031227	1365.88071	-149.85078	20854.48174	774.06804	.09387	777551.34409	.000505	.000000
.082500	.030946	1500.03517	-169.13754	21424.67558	621.31771	.12015	624113.64232	.000626	.000000
.082500	.030559	1587.67324	-182.92320	21123.90707	509.05603	.14459	511346.76013	.000596	.000000
.082500	.030035	1653.48728	-184.57761	21248.61534	420.69120	.17599	422584.30916	.000281	.000000
.082500	.029346	1670.36848	-203.03762	22328.21261	391.57050	.19868	393332.56396	.000062	.000000
.082500	.028474	1683.74256	-183.51539	20268.58505	375.99293	.18783	377684.90010	.000010	.000000
.082500	.027420	1680.99560	-192.14204	21004.27238	379.87616	.19266	381585.60087	.000002	.000000
.082500	.026216	1674.48531	-206.16829	22323.90846	386.84891	.20107	388589.72723	.000001	.000000
.082500	.024927	1679.96388	-184.14661	21400.67316	381.43901	.19549	383155.48809	.000000	.000001
.082500	.023638	1684.27924	-149.13599	21234.56059	378.12336	.19567	379824.91351	.000000	.000001
.082500	.022435	1676.61644	-137.98379	23869.82837	391.32011	.21254	393081.04936	.000000	.000000
.082500	.021381	1669.09743	-150.37669	26157.35794	404.32357	.22542	406143.02259	.000000	.000001
.082500	.020509	1669.07806	-183.67230	25083.17521	397.31669	.21997	399104.61804	.000000	.000002
.082500	.019820	1669.92529	-215.63091	23381.30214	390.87465	.20842	392633.58388	.000002	.000003
.082500	.019296	1663.74045	-175.47543	27344.37458	407.72313	.23368	409557.88697	.000017	.000001
.082500	.018908	1646.28555	-70.29511	37976.16622	448.05501	.29532	450071.25703	.000149	.000002
.082500	.018628	1626.93619	-36.11208	41798.91318	480.62841	.30302	482791.24141	.000536	.000003
.082500	.018428	1558.12728	-26.30672	41791.84687	577.99980	.25193	580600.79916	.000616	.000002
.082500	.018286	1437.55773	-13.07465	43290.19475	739.04716	.20410	742372.86875	.000519	.000000
.082500	.018188	1250.59124	-13.84925	42510.20064	948.35927	.15618	952626.86225	.000399	.000001
.082500	.018119	1071.71643	-6.03502	43165.64131	1117.57226	.13458	1122601.33088	.000344	.000002
.082500	.018071	865.60208	-4.25916	42792.49836	1279.77870	.11651	1285537.70089	.000104	.000003
.082500	.018038	586.90389	1.66831	43023.90209	1423.10408	.10534	1429508.04375	.000018	.000003
.082500	.018016	267.54040	.53586	42971.19190	1488.77445	.10057	1495473.93608	.000001	.000003
.062500	.018000	.00000	.00000	42971.19190	1488.77445	.10057	1495473.93608	.000000	.000003
.082500	.014362	257.94202	-31.70449	24473.19644	1335.15858	.06387	1341166.78876	.000000	.000000
.082500	.014334	584.71437	-82.24051	24617.20662	1273.04066	.06738	1278769.33934	.000011	.000000
.082500	.014293	850.75048	-111.00615	24222.25756	1149.71597	.07341	1154889.69343	.000070	.000000
.082500	.014230	1083.60635	-151.65614	24878.68764	988.04947	.08773	992495.69624	.000182	.000000
.082500	.014133	1266.48235	-167.50022	23969.94329	825.60987	.10116	829325.11520	.000209	.000000
.082500	.013989	1465.73033	-212.01746	25149.41894	632.69228	.13850	635539.39513	.000270	.000000
.082500	.013773	1561.26638	-216.45890	24005.41005	522.66908	.16003	525021.06968	.000174	.000000
.082500	.013455	1639.05709	-230.53868	24985.58220	434.34516	.20043	436299.71807	.000034	.000000
.082500	.012997	1650.56900	-238.77675	26146.25372	417.71018	.21810	419589.87790	.000004	.000000
.082500	.012356	1668.62196	-215.22299	23322.23705	396.98005	.20470	398766.45883	.000000	.000000
.082500	.011495	1647.68176	-273.37145	28518.42230	420.50218	.23631	422394.44367	.000000	.000000
.082500	.010401	1650.36467	-254.77333	26639.86689	414.20683	.22410	416070.75641	.000000	.000000
.082500	.009102	1692.36726	-137.26285	17027.00245	363.72526	.16311	365362.02588	.000000	.000000
.082500	.007683	1724.73146	-40.02671	11498.40179	317.85142	.12605	319281.75610	.000000	.000000
.082500	.006264	1732.47659	-10.26960	10469.69631	303.73396	.12010	305100.75842	.000000	.000000
.082500	.004966	1733.70155	2.88421	10311.41879	301.61352	.11912	302970.77684	.000000	.000000
.062500	.003872	1736.49659	-3.00226	9588.62752	301.95676	.11064	303315.56324	.000000	.000000
.082500	.003011	1713.79186	67.65812	12654.71740	336.48697	.13104	338001.16153	.000000	.000000
.082500	.002370	1662.18952	225.94421	23239.03912	403.92572	.20046	405743.38488	.000000	.000000
.082500	.001912	1653.50732	269.26610	27138.49898	411.83389	.22961	413687.14712	.000001	.000000
.062500	.001594	1659.49103	241.89582	25120.18274	397.07668	.22043	398863.52915	.000016	.000000
.082500	.001378	1621.71685	251.95802	26364.45483	447.17010	.20543	449182.36270	.000120	.000000
.082500	.001233	1524.67339	219.38323	25586.08915	566.95673	.15724	569508.03064	.000191	.000000
.082500	.001137	1298.83159	181.60771	25970.60636	812.80505	.11133	816462.67068	.000146	.000000
.082500	.001074	1013.01014	136.99949	25622.24331	1051.57282	.08490	1056304.89438	.000111	.000000
.082500	.001032	711.13758	100.05549	25827.66485	1229.58098	.07319	1235114.09398	.000018	.000000
.082500	.001005	329.17494	44.80071	25761.44902	1325.11109	.06774	1331074.08549	.000001	.000000
.082500	.000987	.00000	.00000	25761.44902	1325.11109	.06774	1331074.08549	.000000	.000000

APPENDIX E

Flow-Field Output on Lower Surface of Strut

The flow-field output on the lower surface of the strut is printed only for NSTRUT = 1.

XS	YS	US	VS	PS	TS	ROS	SHS	HS	VISS
.055000	.018000	.00000	.00000	21150.10588	1022.61893	.07206	1027220.71965	1027220.719653	.000042
.057500	.017671	.00000	.00000	26808.30404	1204.73457	.07753	1210155.88051	1210155.880506	.000046
.060000	.017342	.00000	.00000	26062.07177	1258.61680	.07215	1264280.57540	1264280.575397	.000048
.062500	.017013	.00000	.00000	26132.18556	1268.71339	.07177	1274422.60142	1274422.601416	.000048
.065000	.016683	.00000	.00000	25678.79887	1306.53963	.06848	1312419.05387	1312419.053874	.000049
.067500	.016354	.00000	.00000	24707.57060	1289.19170	.06678	1294993.05786	1294993.057856	.000048
.070000	.016025	.00000	.00000	25546.14480	1330.53078	.06690	1336518.17092	1336518.170923	.000049
.072500	.015696	.00000	.00000	25998.06986	1330.99596	.06806	1336985.44612	1336985.446119	.000049
.075000	.015367	.00000	.00000	25403.51061	1315.06317	.06731	1320980.95070	1320980.950701	.000049
.077500	.015038	.00000	.00000	25671.50292	1347.91856	.06636	1353984.19774	1353984.197735	.000049
.080000	.014709	.00000	.00000	25094.74709	1342.85261	.06511	1348895.44688	1348895.446879	.000049
.082500	.014380	.00000	.00000	24473.19644	1335.15858	.06387	1341166.78876	1341166.788756	.000049
.085000	.014050	.00000	.00000	25658.71111	1373.16073	.06511	1379339.95690	1379339.956904	.000050
.087500	.013721	.00000	.00000	25440.28089	1361.34970	.06511	1367475.77132	1367475.771321	.000050
.090000	.013392	.00000	.00000	25335.41168	1357.54659	.06503	1363655.55452	1363655.554519	.000050
.092500	.013063	.00000	.00000	25011.34130	1383.89177	.06297	1390119.28628	1390119.286284	.000050
.095000	.012734	.00000	.00000	24701.53615	1368.00297	.06292	1374158.98585	1374158.985851	.000050
.097500	.012405	.00000	.00000	25526.21038	1401.97981	.06344	1408288.71958	1408288.719577	.000051
.100000	.012076	.00000	.00000	16999.82893	1348.00272	.04394	1354068.73128	1354068.731283	.000049
.102500	.012350	.00000	.00000	9323.11786	1315.50394	.02469	1321423.70550	1321423.705498	.000049
.105000	.012625	.00000	.00000	7954.12589	1334.66212	.02077	1340668.10302	1340668.103019	.000049
.107500	.012900	.00000	.00000	7233.42488	1309.19230	.01925	1315083.66731	1315083.667314	.000049
.110000	.013175	.00000	.00000	6951.06819	1353.51634	.01789	1359607.16406	1359607.164064	.000050
.112500	.013449	.00000	.00000	6340.89227	1324.26413	.01668	1330223.31745	1330223.317449	.000049
.115000	.013724	.00000	.00000	6184.38137	1353.23405	.02107	1359323.60707	1359323.607069	.000050
.117500	.013999	.00000	.00000	10494.36405	1074.83447	.03402	1079671.22156	1079671.221560	.000043
.120000	.014273	.00000	.00000	14690.87377	1445.70312	.03541	1452208.78134	1452208.781338	.000052
.122500	.014548	.00000	.00000	20691.04277	1391.46116	.05181	1397722.73432	1397722.734321	.000050
.125000	.014823	.00000	.00000	24926.21714	1450.00748	.05990	1456532.51759	1456532.517593	.000052

Mass Flow Rate Output

BODY STATION NO.= 33	X(METERS)= .09750	MASS FLOW RATE(KG/M/SEC)= 8.07562
BODY STATION NO.= 34	X(METERS)= .10000	MASS FLOW RATE(KG/M/SEC)= 8.05485
BODY STATION NO.= 35	X(METERS)= .10250	MASS FLOW RATE(KG/M/SEC)= 8.05039
BODY STATION NO.= 36	X(METERS)= .10500	MASS FLOW RATE(KG/M/SEC)= 8.05796
BODY STATION NO.= 37	X(METERS)= .10750	MASS FLOW RATE(KG/M/SEC)= 8.03889
BODY STATION NO.= 38	X(METERS)= .11000	MASS FLOW RATE(KG/M/SEC)= 8.05932
BODY STATION NO.= 39	X(METERS)= .11250	MASS FLOW RATE(KG/M/SEC)= 8.04369
BODY STATION NO.= 40	X(METERS)= .11500	MASS FLOW RATE(KG/M/SEC)= 8.06730
BODY STATION NO.= 41	X(METERS)= .11750	MASS FLOW RATE(KG/M/SEC)= 8.05163
BODY STATION NO.= 42	X(METERS)= .12000	MASS FLOW RATE(KG/M/SEC)= 8.07953
BODY STATION NO.= 43	X(METERS)= .12250	MASS FLOW RATE(KG/M/SEC)= 8.06094
BODY STATION NO.= 44	X(METERS)= .12500	MASS FLOW RATE(KG/M/SEC)= 8.09378

APPENDIX E

Flow Spillage Output

BODY STATION NO.=	26	XP=	.092376	LOCAL MASS SPILLED=	.12079	TOTAL MASS SPILLED UPTO XP=	.00386
BODY STATION NO.=	27	XP=	.095263	LOCAL MASS SPILLED=	.12302	TOTAL MASS SPILLED UPTO XP=	.00421
BODY STATION NO.=	28	XP=	.098150	LOCAL MASS SPILLED=	.12871	TOTAL MASS SPILLED UPTO XP=	.00458
BODY STATION NO.=	29	XP=	.101036	LOCAL MASS SPILLED=	.15362	TOTAL MASS SPILLED UPTO XP=	.00498
BODY STATION NO.=	30	XP=	.103923	LOCAL MASS SPILLED=	.17421	TOTAL MASS SPILLED UPTO XP=	.00546
BODY STATION NO.=	31	XP=	.106810	LOCAL MASS SPILLED=	.19476	TOTAL MASS SPILLED UPTO XP=	.00599
BODY STATION NO.=	32	XP=	.109697	LOCAL MASS SPILLED=	.20270	TOTAL MASS SPILLED UPTO XP=	.00656
BODY STATION NO.=	33	XP=	.112583	LOCAL MASS SPILLED=	.22472	TOTAL MASS SPILLED UPTO XP=	.00718
BODY STATION NO.=	34	XP=	.115470	LOCAL MASS SPILLED=	.24052	TOTAL MASS SPILLED UPTO XP=	.00785
BODY STATION NO.=	35	XP=	.118357	LOCAL MASS SPILLED=	.24475	TOTAL MASS SPILLED UPTO XP=	.00855
BODY STATION NO.=	36	XP=	.121244	LOCAL MASS SPILLED=	.24369	TOTAL MASS SPILLED UPTO XP=	.00926
BODY STATION NO.=	37	XP=	.124130	LOCAL MASS SPILLED=	.23774	TOTAL MASS SPILLED UPTO XP=	.00995
BODY STATION NO.=	38	XP=	.127017	LOCAL MASS SPILLED=	.23179	TOTAL MASS SPILLED UPTO XP=	.01063
BODY STATION NO.=	39	XP=	.129904	LOCAL MASS SPILLED=	.22547	TOTAL MASS SPILLED UPTO XP=	.01129
BODY STATION NO.=	40	XP=	.132791	LOCAL MASS SPILLED=	.22048	TOTAL MASS SPILLED UPTO XP=	.01193
BODY STATION NO.=	41	XP=	.135677	LOCAL MASS SPILLED=	.21061	TOTAL MASS SPILLED UPTO XP=	.01256
BODY STATION NO.=	42	XP=	.138564	LOCAL MASS SPILLED=	.19843	TOTAL MASS SPILLED UPTO XP=	.01315
BODY STATION NO.=	43	XP=	.141451	LOCAL MASS SPILLED=	.18332	TOTAL MASS SPILLED UPTO XP=	.01370

Pressure Ratio Output on Lower and Upper Boundaries

N	XP	CENTER LINE PR. RATIO (M = 1)	SIDEWALL PR. RATIO (M = M1)
1	.00000	1.0000	1.0000
2	.00577	1.0070	1.7647
3	.01155	1.0061	2.2301
4	.01732	1.0032	2.2139
5	.02309	1.0109	2.1625
6	.02887	1.0011	2.1627
7	.03406	1.0125	2.1768
8	.03868	1.0005	2.1529
9	.04272	1.0155	2.1663
10	.04619	.9919	2.1424
11	.04907	1.0223	2.1016
12	.05196	.9938	2.0947
13	.05485	1.0200	2.0974
14	.05774	.9956	2.1517
15	.06062	1.0079	2.1632
16	.06351	1.0029	2.1563
17	.06640	.9973	2.1223
18	.06928	.9949	2.1324
19	.07217	1.0030	2.0776
20	.07506	.9906	2.1131
21	.07794	.9900	2.0951
22	.08083	.9968	2.1114
23	.08372	1.0530	2.1145
24	.08660	2.1081	2.1314
25	.08949	2.6353	2.1408

APPENDIX E

Pressure Ratio Output on Lower and Upper Surfaces of Strut

The pressure ratio output on the lower and upper surfaces of the strut is printed only for NSTRUT = 1.

N	YP	STRUT UPPER SURFACE PR. RATIO	STRUT LOWER SURFACE PR. RATIO
16	.06351	1.4932	2.1150
17	.06640	1.2633	2.6808
18	.06928	1.1928	2.6062
19	.07217	1.1509	2.6132
20	.07506	1.1512	2.5679
21	.07794	1.1044	2.4708
22	.08083	1.2087	2.5546
23	.08372	1.2125	2.5998
24	.08660	1.2956	2.5404
25	.08949	1.9811	2.5672
26	.09238	3.1793	2.5095
27	.09526	4.2971	2.4473
28	.09815	4.9100	2.5659
29	.10104	5.0094	2.5440
30	.10392	4.9075	2.5335
31	.10681	4.6010	2.5011
32	.10970	4.3770	2.4702
33	.11258	4.1791	2.5526
34	.11547	3.9674	1.7000
35	.11836	4.1153	.9323
36	.12124	3.5351	.7954

Program Termination Message

PROGRAM TERMINATED ON PHYSICAL TIME CONVERGENCE CRITERION

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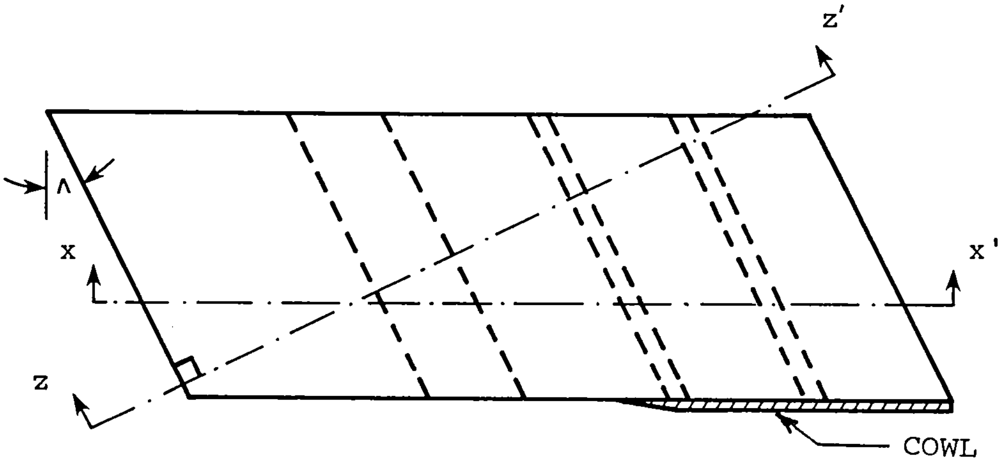
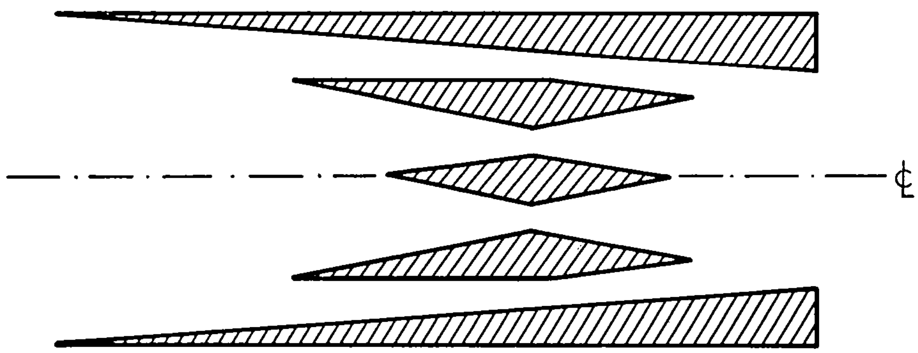
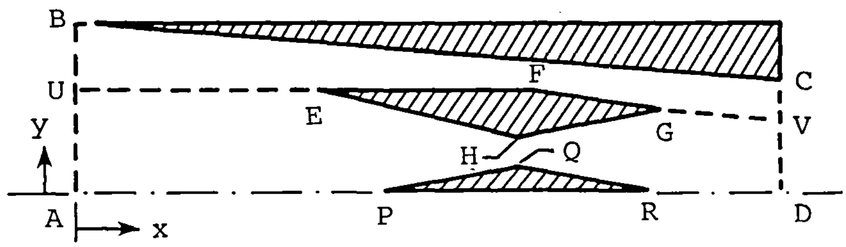


(a) Side view of a scramjet-inlet module.

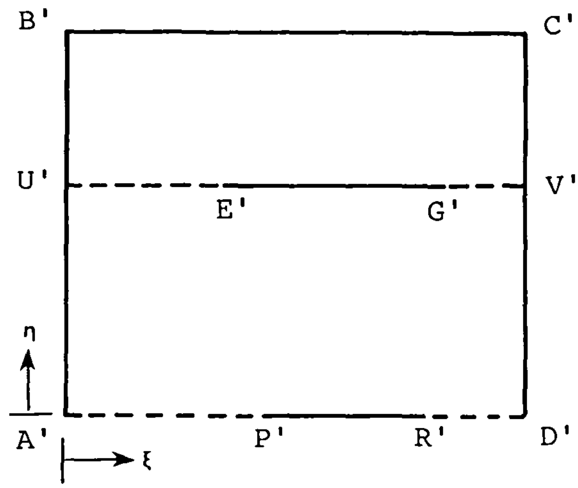


(b) Geometry in plane xx'.

Figure 1.- Geometry of sample problem.



(c) Upper half of geometry in plane zz' (physical plane).



(d) Upper half of geometry in plane zz' (transformed plane).

Figure 1.- Concluded.

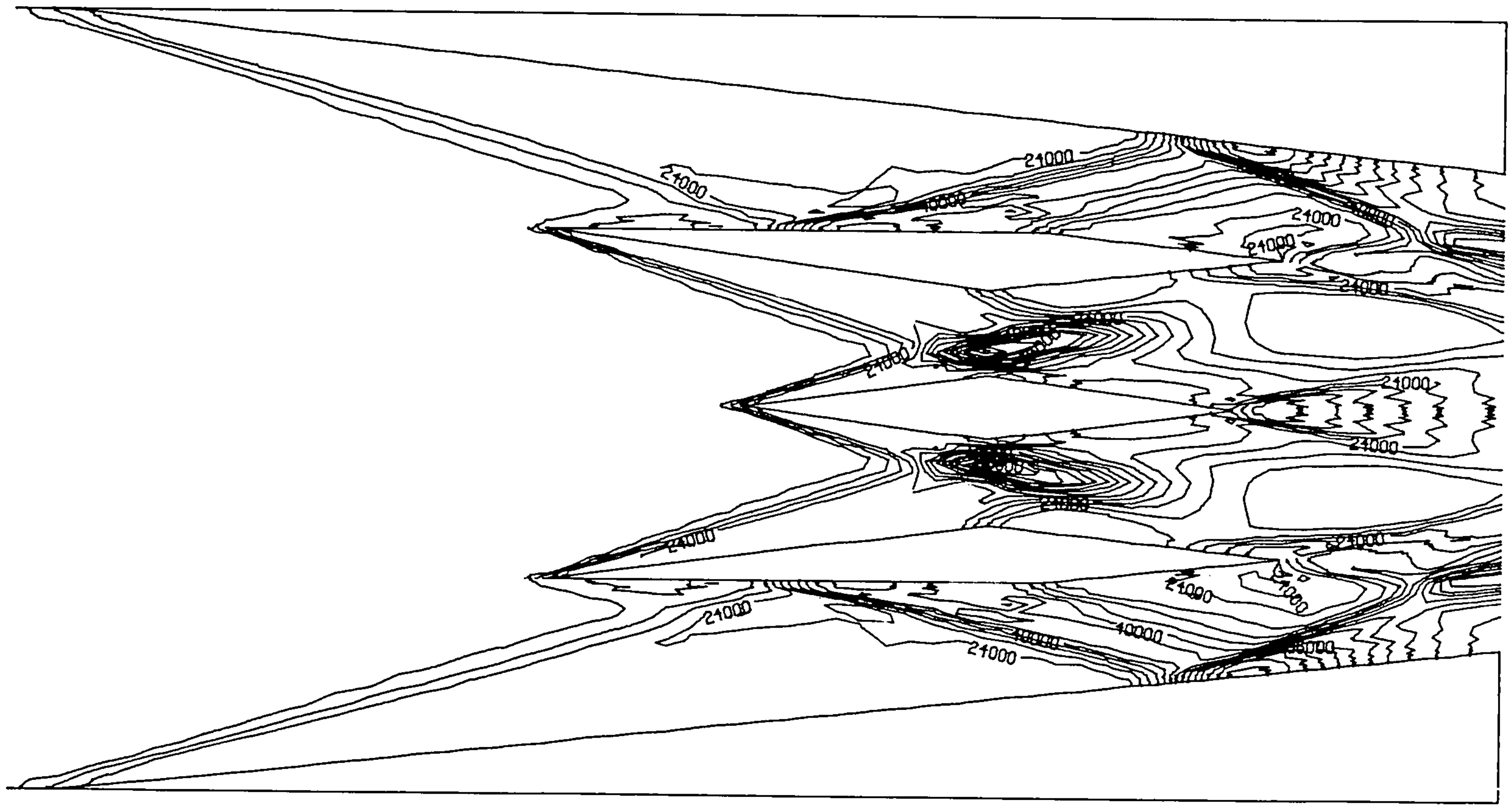


Figure 2.- Pressure contour plot for sample problem.

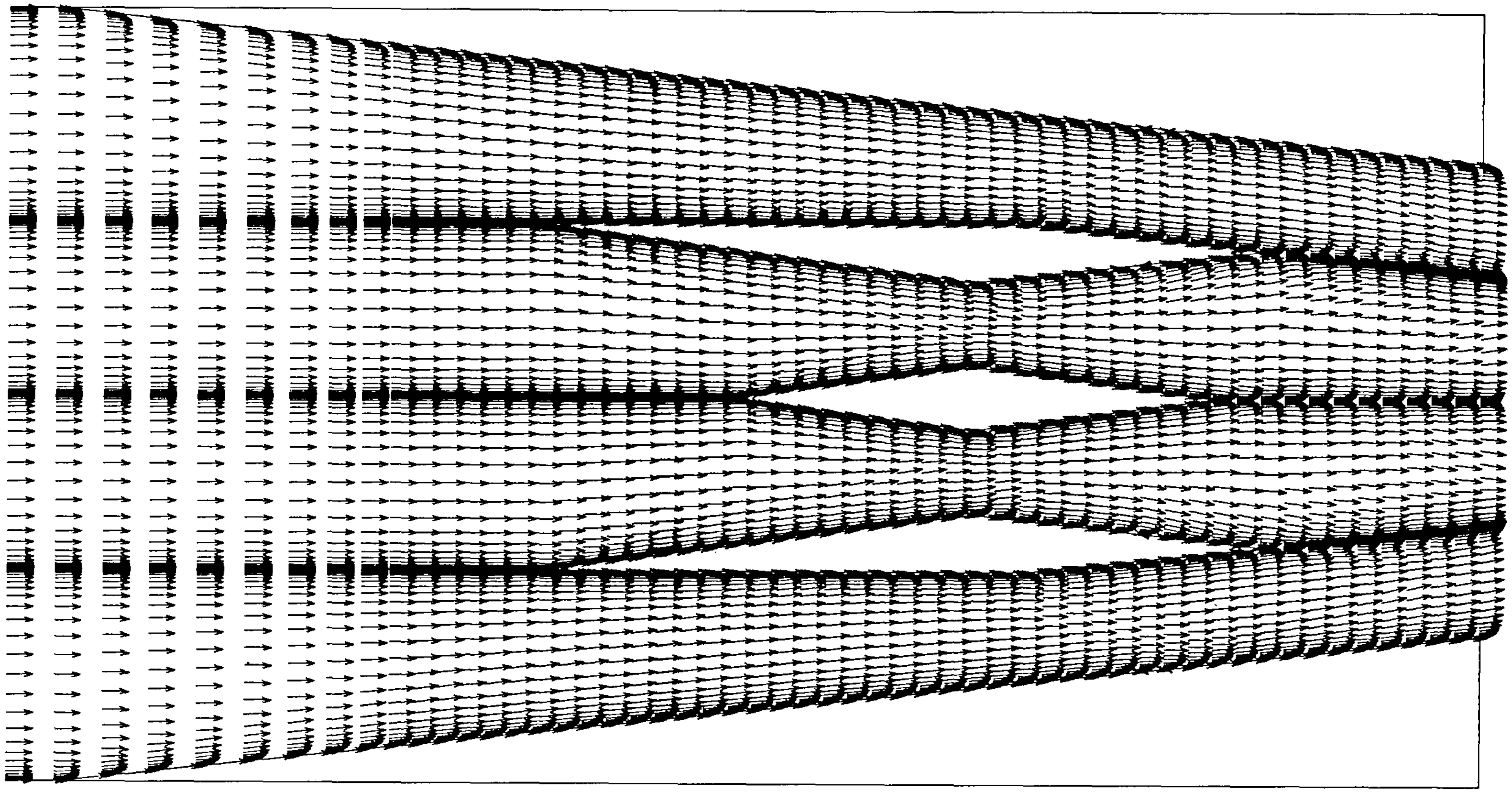


Figure 3.- Velocity vector field for sample problem.

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15. Supplementary Notes

16. Abstract

A computer program NASCRIN has been developed for analyzing two-dimensional flow fields in high-speed inlets. It solves the two-dimensional Euler or Navier-Stokes equations in conservation form by an explicit, two-step finite-difference method. An explicit-implicit method can also be used at the user's discretion for viscous flow calculations. For turbulent flow, an algebraic, two-layer eddy-viscosity model is used. The code is operational on the CDC® CYBER 203 computer system and is highly vectorized to take full advantage of the vector-processing capability of the system. It is highly user oriented and is structured in such a way that for most supersonic flow problems, the user has to make only a few changes. Although the code is primarily written for supersonic internal flow, it can be used with suitable changes in the boundary conditions for a variety of other problems.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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